From the INTERNATIONAL BUREAU

# PCT

## NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

| | |
|---|---|
| **Date of mailing** (day/month/year)<br>15 January 2001 (15.01.01) | |
| **International application No.**<br>PCT/GB00/01715 | **Applicant's or agent's file reference**<br>BKCD/IJ/ENS7 |
| **International filing date** (day/month/year)<br>05 May 2000 (05.05.00) | **Priority date** (day/month/year)<br>07 May 1999 (07.05.99) |
| **Applicant**<br>CAREY, Michael, John et al | |

1. The designated Office is hereby notified of its election made:

   ☒ in the demand filed with the International Preliminary Examining Authority on:

   05 December 2000 (05.12.00)

   ☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was ☐ was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).



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| **The International Bureau of WIPO**<br>**34, chemin des Colombettes**<br>**1211 Geneva 20, Switzerland**<br>Facsimile No.: (41-22) 740.14.35 | Authorized officer<br>Juan Cruz<br>Telephone No.: (41-22) 338.83.38 |

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REC'D 22 AUG 2001
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# PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

| | | |
|---|---|---|
| Applicant's or agent's file reference<br>BKCD/IJ/ENS.7 PCT | **FOR FURTHER ACTION** | See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416) |
| International application No.<br>PCT/GB00/01715 | International filing date *(day/month/year)*<br>05/05/2000 | Priority date *(day/month/year)*<br>07/05/1999 |
| International Patent Classification (IPC) or national classification and IPC<br>G10L21/02 | | |
| Applicant<br>IMAGINATION TECHNOLOGIES LIMITED et al. | | |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☒ Certain defects in the international application
   VIII ☐ Certain observations on the international application

| | |
|---|---|
| Date of submission of the demand<br>05/12/2000 | Date of completion of this report<br>20.08.2001 |
| Name and mailing address of the international preliminary examining authority:<br>European Patent Office<br>D-80298 Munich<br>Tel. +49 89 2399 - 0 Tx: 523656 epmu d<br>Fax: +49 89 2399 - 4465 | Authorized officer<br>Greiser, N<br>Telephone No. +49 89 2399 7402 |

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/01715

### I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

**Description, pages:**

1-29 as originally filed

**Claims, No.:**

1-31 as originally filed

**Drawings, sheets:**

1/8-8/8 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   *(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

6. Additional observations, if necessary:

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

| | | | |
|---|---|---|---|
| Novelty (N) | Yes: | Claims | 1-31 |
| | No: | Claims | |
| Inventive step (IS) | Yes: | Claims | 2-17;19-29 |
| | No: | Claims | 1,18,30-31 |
| Industrial applicability (IA) | Yes: | Claims | 1-31 |
| | No: | Claims | |

2. Citations and explanations
   **see separate sheet**

**VII. Certain defects in the international application**

The following defects in the form or contents of the international application have been noted:
**see separate sheet**

To Section V:

1. Claim 1 does not meet the requirement of Article 33(3) PCT for the following reason:

   Maintaining performance in the presence of interfering signals is a well known problem associated with speech recognizers. In the prior art, adaptive filters are known to tackle the above problem.

   Document D1= US-A-4630304 (introduced by the International Preliminary Examining Authority; a copy is enclosed), for example, discloses an apparatus for cancellation of quasi-stationary interfering signals whereby said apparatus includes (see col. 3, l. 36-61; fig. 1):
   - means for receiving an acoustic signal;
   - means for generating an estimated value of a magnitudes spectrum of said quasi-stationary interfering signals (see col. 3, 53-57); and
   - means for subtracting said estimated value from said received acoustic signal to produce a representation of a wanted speech magnitudes spectrum (see col. 3, l. 58-61).

   In an attempt to overcome the problem of non-stationary interfering signals, it would readily occur to a skilled person to employ the above apparatus for cancellation of interfering signals. As a result, the subject-matter of claim 1 would be obvious to the skilled person and, hence, claim 1 does not involve an inventive step.

2. Claim 18 claims a method of cancellation of one or more non-stationary interfering signals for speech recognition. Since method claim 18 corresponds to apparatus claim 1, the objection of lack of inventive step raised against claim 1 applies to claim 18 as well. Moreover, claims 30-31 as far as dependent upon claim 1 are not inventive.

3. Claims 2-17 and 19-29 are new and appear to involve an inventive step.

To Section VII:

4. Document D1 discloses background art which is not identified in the description; furthermore, the relevant prior art disclosed therein is not discussed (Rule 5.1(a)(ii) PCT).

PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

| Applicant's or agent's file reference<br>BKCD/IJ/ENS7 | **FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below. | |
|---|---|---|
| International application No.<br>PCT/GB 00/ 01715 | International filing date *(day/month/year)*<br>05/05/2000 | (Earliest) Priority Date *(day/month/year)*<br>07/05/1999 |
| Applicant<br>ENSIGMA LIMITED et al. | | |

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

      [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

      [ ] contained in the international application in written form.
      [ ] filed together with the international application in computer readable form.
      [ ] furnished subsequently to this Authority in written form.
      [ ] furnished subsequently to this Authority in computer readble form.
      [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
      [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01715

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 G10L21/02 G10L15/20

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX, IBM-TDB

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP 0 856 834 A (NIPPON ELECTRIC CO)<br>5 August 1998 (1998-08-05)<br>abstract; claim 1; figure 5<br>--- | 1,2,18,<br>19 |
| A | US 5 864 804 A (KALVERAM HANS)<br>26 January 1999 (1999-01-26)<br>abstract; figure 2<br>column 2, line 1 - line 15<br>column 2, line 61 - line 65<br>----- | 1,2,18,<br>19 |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 15 August 2000 | 22/08/2000 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Van Doremalen, J |

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/01715

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| EP 0856834 A | 05-08-1998 | JP 2930101 B | 03-08-1999 |
| | | JP 10215194 A | 11-08-1998 |
| | | AU 5278798 A | 06-08-1998 |
| | | CA 2228121 A | 29-07-1998 |
| | | US 5978824 A | 02-11-1999 |
| US 5864804 A | 26-01-1999 | DE 19521258 A | 12-12-1996 |
| | | EP 0747880 A | 11-12-1996 |
| | | JP 9006388 A | 10-01-1997 |

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WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(30) Priority Data:
9910448.1 7 May 1999 (07.05.99) GB

(71) Applicant *(for all designated States except US)*: IMAGINATION TECHNOLOGIES LIMITED [GB/GB]; Home Park Estate, Kings Langley, Hertfordshire WD4 8LZ (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: CAREY, Michael, John [GB/GB]; Ensigma Limited, Turing House, Station Road, Chepstow NP6 6PB (GB). TATTERSALL, Graham, David [GB/GB]; New House, Friston, Saxmundham, Suffolk IP17 1PH (GB).

(74) Agents: DUNLOP, Brian, Kenneth, Charles et al.; Wynne-Jones, Laine & James, 22 Rodney Road, Cheltenham, Gloucestershire GL50 1JJ (GB).

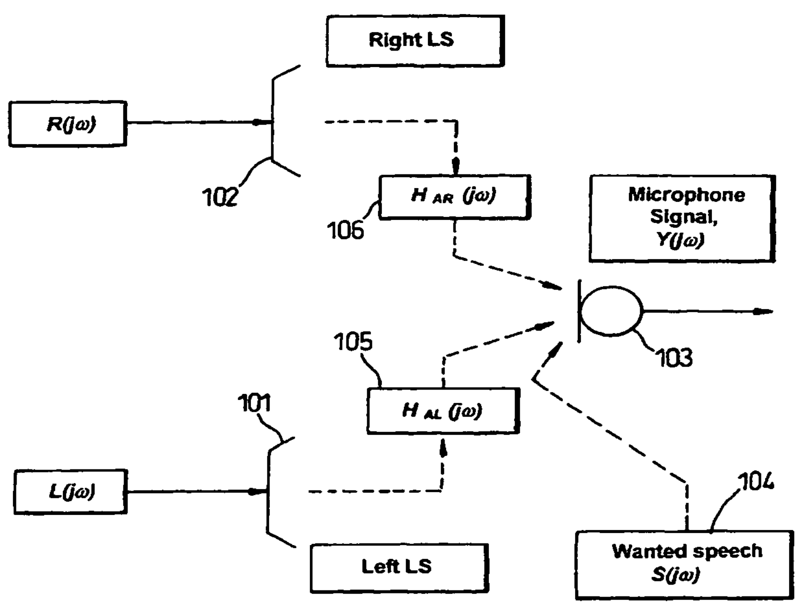
(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published**
*With international search report.*

(54) Title: CANCELLATION OF NON-STATIONARY INTERFERING SIGNALS FOR SPEECH RECOGNITION

(57) Abstract

System for cancellation of non-stationary interfering signals, particularly for use for mitigating effects of such interferers produced by in-car entertainment (ECAD) devices for speech recognition applications. The system spectrally analyses signals output by the ECAD before and after they are passed through an in-car acoustic channel. A model of the acoustic channel is built by the system's algorithm. For speech recognition the model is spectrally subtracted from a signal received at a microphone in order to recover a wanted speech signal. The acoustic channel model is built by estimating frequency domain acoustic transfer functions between each loudspeaker used by the ECAD and the microphone.



*FOR THE PURPOSES OF INFORMATION ONLY*

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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# Cancellation of Non-Stationary Interfering Signals for Speech Recognition

This invention relates to apparatus and method for cancellation of non-stationary interfering signals. In particular, the invention relates to cancellation of such signals for the purpose of recovering a wanted speech signal for use by a speech recognition application. The invention is especially suitable for use in an automobile where in-car devices produce interfering signals during the speech recognition process.

A problem associated with speech recognition is that of maintaining performance in the presence of interfering signals so that the speech recognition process continues to function satisfactorily even in the presence of background noise. Known systems have been directed towards mitigating effects of quasi-stationary noise such as telephone channel noise or car noise. Proposed solutions to quasi-stationary noise interference include spectral subtraction, Weiner filtering and parallel model combination, each of which work in the spectral domain.

There are, however, other sources of interference in acoustic environments which may degenerate performance of speech recognition applications. In the example of an automobile environment, in addition to engine noise, another source of potentially interfering non-stationary acoustic signals includes sound generated by electronic devices operating in the car. Examples of such devices include in-

car entertainment accessories such as radios, compact disc players and tape players and also other types of devices which may emit sonic signals, e.g. telephone ringing or navigation system warning tones. In this specification, electronic devices capable of emitting acoustic signals and operating in a vehicle are generically referred to as "Electronic in-car Acoustic Devices" (ECAD).

Sound generated by ECAD could be present when a user wishes to control a device using a voice command. For example, a radio may be playing in a car when the user wants to use voice control of a navigation system or the radio itself. In this case, the original interfering signal produced by the radio is assumed to be known and accessible but has passed through an unknown acoustic path between the radio's loudspeakers and the speech recognition system's microphone. The acoustic path may be determined by the position of the loudspeakers and the microphone inside the car as well as other factors, such as the number of passengers and the presence of luggage inside the car.

Known systems which attempt to overcome the problem of non-stationary interferers have been based on time domain adaptive filters. However, although adaptive filtering may produce satisfactory results, this approach suffers from a number of disadvantages. Such disadvantages include high computational requirements and slow convergence of adaptive filtering algorithms. Simple forms of adaptive filtering may require order 3N computations per sample. Such high computational requirements can mean that complex hardware

may be required in order to perform the necessary filtering, thereby increasing costs of devices incorporating such technology to the consumer.

According to a first aspect of the present invention, there is provided apparatus for cancellation of one or more non-stationary interfering signals for speech recognition, said apparatus comprising:

means for receiving an acoustic signal;

means for generating an estimated value of a magnitude spectrum of said non-stationary interfering signals; and

means for subtracting said estimated value from said received acoustic signal to produce a representation of a wanted speech magnitude spectrum.

Preferably, said means for generating estimated value includes processing means configured to estimate a transfer function for an acoustic channel between each source of said non-stationary interfering signals and said means for receiving an acoustic signal.

Preferably, said processing means is configured to estimate transfer functions for non-stationary interfering signals produced by left and right stereo channel transmissions.

Preferably, said estimation of said transfer functions is achieved by said processing means executing an iterative algorithm on a frame-by-frame basis, the frames being constituted by successive time periods.

Preferably, said processing means is configured to estimate magnitudes of said left and right channel interfer-

ence signals,

said magnitude of left channel interference signal estimated by subtracting said right channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iteration; and

said magnitude of right channel interference signal is estimated by subtracting said left channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iteration.

Preferably, said transfer function estimate for said right stereo acoustic channel is determined by dividing said right channel interference magnitude estimate by said interfering signal transmitted from said right acoustic stereo channel; and

said transfer function estimate for said left stereo acoustic channel is determined by dividing said left channel interference magnitude estimate by said interfering signal transmitted from said left acoustic stereo channel.

Preferably, said right acoustic channel transfer function estimation is performed for a said iteration only if a ratio of total energy of said right acoustic stereo channel interfering signal over total energy of said left acoustic stereo interfering channel exceeds a predetermined threshold value; and

said left acoustic channel transfer function estimation is performed for a said iteration only if a ratio of total

energy of said left acoustic stereo channel interfering signal over total energy of said right acoustic stereo channel interfering signal exceeds a predetermined threshold value.

Preferably, said ratio and threshold comparisons are applied to individual frequency components in spectra of said signals.

Preferably, said left and right stereo acoustic channel transfer functions are multiplied by $(1-|\eta(k)|)$ where $\eta(k)$ is coherence of said left and right interfering signals at a frequency index k.

Preferably, said transfer function estimate for said right stereo acoustic channel is obtained using an expression:

$$\hat{H}_{AR}(k) = \frac{Y(k)}{R''(k)} = \frac{H_{AR}(k)\,.\,R''(k)}{R''(k)} = H_{AR}(k)$$

and said transfer functions estimate for said left stereo acoustic channel is obtained using an expression:

$$\hat{H}_{AL}(k) = \frac{Y(k)}{L''(k)} = \frac{H_{AL}(k)\,.\,L''(k)}{L''(k)} = H_{AL}(k)$$

wherein $R''(k)=H_{CR}(k).C(k)$, with $C(k)$ being a common component of said left and right stereo channel signals and $H_{CR}(k)$ is a transfer function between common said left and right stereo channel transmissions, and said right stereo channel and $L''(k)=L(k)-H_{CL}(k).C(k)$, where $H_{CL}(k)$ is a transfer function between common said left and right stereo channel

transmissions and said left stereo channel signal.

Preferably, wherein said processing means further comprises means for smoothing said estimated transfer functions in time domain.

Preferably, wherein said means for smoothing in time domain comprises a first order recursive filter.

Preferably, said processing means further comprises means for smoothing said estimated transfer functions in frequency domain.

Preferably, said means for smoothing in frequency domain comprises a Finite Impulse Response filter.

Preferably, said processing means includes means for performing a Fourier Transform.

Preferably, said non-stationary interfering signals are produced by an electronic acoustic device operating in a vehicle.

Preferably, said means for receiving an acoustic signal comprises a microphone.

According to a second aspect of the present invention there is provided a method of cancellation of one or more non-stationary interfering signals for speech recognition, said method comprising steps of:

receiving an acoustic signal;

generating an estimated value for a magnitude spectrum of said non-stationary interfering signal; and

subtracting said estimated value from said received acoustic signal to produce a representation of a wanted speech magnitude spectrum.

Preferably, said step of generating an estimated value comprises estimating a transfer function for an acoustic channel between each source of said non-stationary interfering signals and said means for receiving an acoustic signal.

Preferably, said transfer functions are estimated for non-stationary interfering signals produced by left and right stereo channel transmissions.

Preferably, said step of generating an estimated value is executed iteratively on a frame-by-frame basis.

Preferably, said step of estimating a transfer function includes:

estimating a magnitude of said left channel interference signal by subtracting said right channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iterations; and

estimating magnitude of said right channel interference signal by substracting said left channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iteration.

The method may further comprise steps of:

dividing said right channel interference magnitude estimate by said interfering signal transmitted from said right acoustic stereo channel; and

dividing said left channel interference magnitude estimated by said interfering signal transmitted from said left acoustic stereo channel.

Preferably, said step of estimating right acoustic

channel transfer function is performed for a said iteration only if a ratio of total energy of said right acoustic stereo channel interfering signal over total energy of said left acoustic stereo channel interfering signal exceeds a predetermined threshold value; and

said step of estimating left acoustic channel transfer function estimate is performed for a said iteration only if a ratio of total energy of said left acoustic stereo channel interfering signal over total energy of said right acoustic stereo channel interfering signal exceeds a predetermined threshold value.

Preferably, said ratio and threshold comparisons are applied to individual frequency components in spectra of said signals.

Preferably, said left and right stereo acoustic channel transfer functions are multiplied by $(1-|\eta(k)|)$ where $\eta(k)$ is coherence of said left and right interfering signals at a frequency index k.

Preferably, said transfer function estimate for said right stereo acoustic channel is obtained using an expression:

Preferably, this aspect may be comprising a step of smoothing said estimated transfer functions in time domain.

Preferably, this aspect may be further comprising a step of smoothing said estimated transfer functions in frequency domain.

According to a third aspect of the present invention, there is provided a speech recognition system including

apparatus according to the first aspect of the invention. According to a fourth aspect of the present invention, there is provided an electronic acoustic device including apparatus according to the first aspect of the invention.

The present invention is a frequency domain (rather than time domain as used in known systems) technique solution which is preferably based on channel identification followed by spectral subtraction. Embodiments of the present application's system can substantially improve performance of a speech recognition system when non-stationary interferers are present whilst having the advantage of lower computational requirement than known systems.

Embodiments of the present application's system provide levels of non-stationary interferer cancellation sufficient to substantially improve the performance of a speech recognition system, typically about 10 decibels of cancellation is possible in the case where loud background music is being output by ECAD. Such levels of cancellation may not be satisfactory to a human listener, however. For the purposes of speech recognition applications, such levels of cancellation will substantially improve the system's performance. A human listener is sensitive to levels of interference 40 decibels below the level of wanted signal, whilst known speech recognition systems can operate well with a 15 decibel signal-to-noise ratio.

The interfering signal output by an ECAD such as a radio may be a mono or stereo transmission, typically being output from two loudspeakers located at separate locations

within an automobile. For the purposes of the description, it is generally assumed that a phase of the interferer signal is not required at the speech recognition system, as recognition feature sets such as cepstra do not normally contain phase information.

The invention may be performed in various ways and, by way of example only, a specific embodiment thereof will now be described, reference being made to the accompanying drawings, in which:

Figure 1 illustrates schematically an example of an automobile environment having an ECAD where a speech recognition system is used to control an in-car device;

Figure 2 illustrates a flow diagram representing steps which may be used to estimate transfer functions representing a model of an in-car acoustic channel;

Figure 3 illustrates schematically components which may be used to implement a refinement of the algorithm in Figure 2;

Figure 4 illustrates a block diagram representing a specific embodiment of the present invention; and

Figures 5 to 8 illustrate examples of microphone signals obtained during experimental use of the present invention.

Figure 1 illustrates schematically a simple situation in which stereo ECAD signals are transmitted from separate loudspeakers. Left stereo signal $L(j\omega)$ is transmitted from left loudspeaker 101 and right stereo signal $R(j\omega)$ is transmitted from right stereo speaker 102.

Loudspeakers 101 and 102 are typically located in panelling on driver and passenger's doors. Further loud-speakers may also be fitted in the vehicle, for example they may be located in a boot compartment at the rear of the car. It will be appreciated by those skilled in the art that the specific embodiment described herein intended for use with two loudspeakers could be modified to function with differ-ent numbers of loudspeakers, which may or may not be configured to generate signals which correlate with signals being output from other loudspeakers present in the car.

Figure 1 also includes a microphone 103 which is preferably connected to an in-car electronic device such as the radio for the purpose of receiving acoustic signals which may be used by a speech recognition system for controlling the device.

A user's voice command which may be processed by the speech recognition system in order to control the electronic device is represented by wanted speech signal $S(j\omega)$104.

A spectrum of the acoustic signal received at the microphone, denoted by $Y(\omega)$, comprises components including a combination of the wanted speech $S(j\omega)$ and the signals produced by the loudspeaker having passed through an acoustic channel defined by the in-car environment.

Perfect cancellation of the unwanted ECAD stereo signals $L(j\omega)$ and $R(j\omega)$ could in principle be achieved given knowledge of acoustic transfer functions $H_{AR}(j\omega)$ for the acoustic path between the right loudspeaker 102 and micro-phone 103 and acoustic transfer function $H_{AL}(j\omega)$ for the

acoustic path between the left loudspeaker 101 and microphone 103. If the transfer functions $H_{AL}(j\omega)$ and $H_{AR}(j\omega)$ were known, it would be possible to retrieve a signal corresponding to the wanted speech command spoken by the user by subtracting the left stereo source signal $L(j\omega)$ transferred by $H_{AL}(j\omega)$ and the right source signal $R(j\omega)$ transferred by $H_{AR}(j\omega)$ from the signal $Y(j\omega)$ received at microphone mono 103. However, in practice although source signals $L(j\omega)$ and $R(j\omega)$ may be accessible from the radio which produced them, the acoustic transfer functions $H_{AR}(j\omega)$ and $H_{AL}(j\omega)$ can only be estimated.

A simple approach to the estimation of the acoustic transfer function is to find the long term ratio of microphone signal spectrum to each of the source stereo signals. Equations herein below describe this process for the right acoustic channel. Those skilled in the art will understand that a similar set of equations can be derived for the left acoustic channel. A basic transfer function $H_{AR}$ for the right acoustic channel may be written as follows:

$$\hat{H}_{AR}(j\omega)=\frac{Y(j\omega)}{R(j\omega)}$$

Equation (1)

A spectrum of the signal $Y(j\omega)$ received at the microphone signal may be written as:

$$Y(j\omega)=H_{AR}(j\omega).R(j\omega)+H_{AL}(j\omega).L(j\omega)+S(j\omega)$$

Equation (2)

Substituting for $Y(j\omega)$ in equation (1) gives:

$$\hat{H}_{AR}(j\omega) = H_{AR}(j\omega) + H_{AL}(j\omega) \cdot \frac{L(j\omega)}{R(j\omega)} + \frac{S(j\omega)}{R(j\omega)}$$

Equation (3)

The following conclusions may be drawn from equation(3):

- In the case of a mono transmission being output through loudspeakers 101 and 102 whilst the user is saying a voice command, signals $L(j\omega)$ and $R(j\omega)$ are completely correlated with each other whilst being completed uncorrelated with $S(j\omega)$. In this case, individual left and right channel transfer functions cannot be uniquely determined, but a composite estimate which contains terms due to both left and right channels can be obtained. This is sufficient for practical cancellation of the mono ECAD signal output through the two loudspeakers received at the microphone.
- If $L(j\omega)$ and $R(j\omega)$ and $S(j\omega)$ are all uncorrelated, a correct estimate of the channel response will be obtained because second and third terms in equation (3) will normally have long term averages of 0.
- If $L(j\omega)$ and $R(j\omega)$ are partially correlated, left and right acoustic channels cannot be unambiguously estimated. However, if $L(j\omega)$ and $R(j\omega)$ occupy different spectral regions or if corresponding time domain signals $l(t)$ and $r(t)$ have periods where one has low energy whilst the other has high energy, it may be still possible to make useful estimates of left and right channels for purposes of cancellation.

The frequency domain estimation of the right acoustic

channel response given by equation (3), and a corresponding equation for the left acoustic channel transfer function, $H_{AL}(j\omega)$, may be used to obtain an estimate of the magnitude of the wanted speech spectrum $S(j\omega)$. An estimate of the wanted speech magnitude spectrum may be obtained by subtracting the estimates of the left and right acoustic channels of the ECAD signals from the acoustic signal $Y(j\omega)$ received at the microphone:

$$\hat{S}^2(\omega) = Y^2(\omega) - \hat{H}^2_{AR} . R^2(\omega) - \hat{H}^2_{AL} . L^2(\omega)$$

Equation (4)

An estimate of the acoustic channel power transfer function for the right acoustic channel, derived by squaring equation (3) may be as follows:

$$\hat{H}^2_{AR}(\omega) = H^2_{AR}(\omega) + H^2_{AL}(\omega) . \frac{L^2(\omega)}{R^2(\omega)} + \frac{S^2(\omega)}{R^2(\omega)}$$

Equation (5)

A corresponding estimate of the acoustic channel power transfer function for the left acoustic channel can also be derived by those skilled in the art.

Using an iterative approach, coupled with time and frequency dimension smoothing of the estimates of the channel response may be used to overcome problems caused by left and right signal correlation described herein above. Another problem which may need to be addressed arises because phase information in the channel response may be ignored, as the phase of the interferer is not normally required at the speech recognition system. As noted above,

cancellation for the purpose of speech recognition only requires an estimate of the magnitude of the speech spectrum because Mel Frequency Cepstral Co-efficient (MFCC) feature vector used by the speech recognition system in the preferred embodiment is based on magnitude spectra. The MFCC may be obtained by subjecting the speech spectrum in the frequency domain to a fast fourier transform in order to obtain its power in various frequency slots. The value of the power in the frequency domain is then passed through a log function and then a cosine transform to obtain the cepstrum in which the elements are orthogonal.

Normally, the phase characteristic encodes a frequency dependent delay spread associated with the acoustic transfer function. In a car typically the minimum delay is about 3ms. The delay spread may be compensated when making the channel estimate using equation (5). However, this compensation may be unnecessary if the spectral evaluation is done using a fast fourier transformer with block length much greater than the channel delay.

A practical form of the cancellation of non-stationary interferer signals such as those produced by ECAD may therefore be achieved using an algorithm 200 as illustrated by steps in Figure 2 of the accompanying drawings. In the preferred embodiment, the steps 201 to 205 are repeated once for each single frame (i.e a signal received at the microphone in a fixed period of time), however, initialisation steps 201 and 202 may only be performed for a first frame. At step 201, estimates of magnitudes of the left and right

channel transfer functions, $H_{AL}(J\omega)$ and $H_{AR}(J\omega)$ are initialised (set to zero):

$$\bar{H}^2_{AR}(\omega) = \bar{H}^2_{AL}(\omega) = 0$$

At step 202, estimates of magnitude of left and right channel interference, $C_L$ and $C_R$, are initialised:

$$C^2_{R,n-1}(\omega) = C^2_{L,n-1}(\omega) = 0$$

At step 203, new estimates of magnitudes of the left and right interference signals at the microphone are calculated. This is achieved for the left microphone signal by subtracting the channel estimate of the magnitude of the right channel (calculated during the algorithm iteration for the immediately previous frame) from the microphone signal received at the current iteration (n). For the right interference channel, the magnitude estimate for the left channel derived during the previous iteration (n-1) is subtracted from the microphone signal:

$$C^2_{L,n}(\omega) = Y^2_n(\omega) - C^2_{R,n-1}(\omega)$$

(Equation 6)

$$C^2_{R,n}(\omega) = Y^2_n(\omega) - C^2_{L,n-1}(\omega)$$

(Equation 7)

At step 204, rough estimates of the left and right transfer functions, $H_{AL}(j\omega)$ and $H_{AR}(j\omega)$, are made. This is achieved for the left channel transfer function by dividing

the estimated left interference signal calculated at step 203 by the signal transmitted from the left stereo acoustic channel. For the right transfer function, the right channel interference signal estimate calculated at step 203 is divided by the signal transmitted from the right acoustic stereo channel:

$$\hat{H}^2_{AL,n}(\omega) = \frac{C^2_{L,n}(\omega)}{L^2_n(\omega)}$$

(Equation 8)

$$\hat{H}^2_{AR,n}(\omega) = \frac{C^2_{R,n}(\omega)}{R^2_n(\omega)}$$

(Equation 9)

Substituting equations (6) and (7) into the terms for the estimated interference signals in equations (8) and (9), respectively, gives expressions used to provide rough estimates of the left and right channel transfer functions:

$$\hat{H}^2{}_{ALn}(\omega) = \frac{\hat{Y}^2{}_n(\omega) - C^2{}_{R,n-1}(\omega)}{L^2{}_{n(\omega)}}$$

$$\hat{H}^2{}_{ARn}(\omega) = \frac{\hat{Y}^2{}_n(\omega) - C^2{}_{L,n-1}(\omega)}{R^2{}_{n(\omega)}}$$

At step 205 the rough estimates of the channel transfer functions obtained at step 204 may be smoothed, preferably both in the time and frequency domains. Time smoothing is preferably achieved with a first order recursive filter using a time constant of several hundred milliseconds. For example, time smoothing for the right channel may be as follows (a similar equation may also be obtained):

$$\overline{H}^2_{AR,n} = \beta . \overline{H}^2_{AR,n-1} + (1-\beta) . \hat{H}^2_{AR,n}$$

Frequency smoothing is preferably achieved using a Finite Impulse Response filter (represented by $f(\omega)$ in an equation herein below) with a triangular impulse response covering about 300 Hertz. Frequency smoothing for the right channel may be as follows (a similar expression for the left channel may also be obtained):

$$\tilde{H}_{AR,n} = f(\omega) * \overline{H}^2_{AR,n}(\omega)$$

The cancellation algorithm 200 described in steps 201 to 205 herein above may be refined by means of the four ways described herein below in order to attempt to deal with problems highlighted by equation (3) concerning correlation of left and right channel signals:

1. Updating of the recursive filter providing the smoothed channel estimate can be inhibited unless energy of one channel greatly exceeds energy of the other channel. This is preferably achieved by updating the left or right channel response only when it is assumed that only left or right channel, respectively, is active. Thus, a new right

acoustic channel transfer function would be estimated at step 204 if a ratio of the total energy of the signal transmitted from the right acoustic stereo channel by the total energy of the signal transmitted from the left stereo acoustic channel exceeds a predetermined threshold value, otherwise the estimate calculated for the transfer function during the previous frame iteration is used. A correspon-ding estimation would also be performed for the left transfer function.

Using $E_L$ to represent the total energy in the $n_{th}$ frame of the left stereo acoustic channel and $E_R$ represent the total energy in the $n_{th}$ frame of the right stereo acoustic channel. Thus, the channel response estimation algorithm for the right channel is:

$$\hat{H}_{AR,n}=\frac{Y(j\omega)}{R(j\omega)}\ if\ \frac{E_R}{E_L}\geq Threshold$$

otherwise use previous estimate $(\hat{H}_{AR,n-1})$ if $E_R/E_L <$ Threshold.

The channel response estimation algorithm for the left channel is:

$$\hat{H}_{AL,n}=\frac{Y(j\omega)}{L(j\omega)}\ if\ \frac{E_L}{E_R}\geq Threshold,$$

otherwise use previous estimate $(\hat{H}_{AL,n-1})$ if $E_R/E_L <$ Threshold.

Normally, when considering the right channel, when the threshold is exceeded, $Y(j\omega)$ should consist mainly of terms due to the right channel and the wanted speech signal. $Y(j\omega)$ should contain very little energy due to the left channel if the threshold is set at high value. The reverse normally holds when considering the left channel. Time and domain smoothing substantially as described at step 205 would also be used.

2. Updating of recursively smoothed channel estimate at particular frequencies can be inhibited unless energy at that frequency in one channel greatly exceeds the energy at that frequency in the other channel. This may be achieved by estimating new values for the left and/or right acoustic channel transfer functions when a ratio of the total energies of the left and right stereo acoustic signals exceeds a given threshold at individual frequency components in the spectrum. Preferably, the threshold may apply to frequencies comprising a harmonic number in the Discreet Fourier Transforms of the signals.

Using a similar terminology to that in 1. herein above, the channel response estimation algorithm for the right channel is:

$$\hat{H}_{AR,n}(k)=\frac{Y(k)}{R(k)}\, if \frac{E(k)_R}{E(k)_L}\geq Threshold$$

Otherwise use estimate at previous iteration ($\hat{H}_{AR,n-1}$) if $E(k)_R/E(k)_L <$ Threshold.

The channel response estimation algorithm for the left channel is:

$$\hat{H}_{AL,n}(k) = \frac{Y(k)}{L(k)} \; if \; \frac{E(k)_L}{E(k)_R} \geq Threshold$$

otherwise use the estimate calculated at the previous iteration ($\hat{H}_{AL,n-1}$) if $E(k)_L/E(k)_R$ < Threshold.

In this definition, the index k refers to the harmonic number in the DFTs of the signals. For example, $E(k)_R$ is the energy of the kth harmonic in the DFT of the right stereo source signal. This algorithm should ensure that the acoustic channel responses are only updated at those frequencies and at those time at which the signal at the microphone consists mainly of either left or right channel.

3. Evaluate coherence function between the left and right channel signals and use inverse magnitude of the coherence at each frequency as a weighting on the amount by which estimates of the channel responses are updated at that frequency. The coherence function provides a measure of correlation over a period of time of phases of two different signals measured at a particular frequency. The coherence function may be used in various ways, normally based on the idea that the update of the acoustic channel responsible will be decreased if the left and right stereo channels are phase-correlated at a particular frequency. If the coherence approaches unity, the signals are correlated, but only

at the specified frequency. Thus, the channel response estimates for the right channel may be derived from the following algorithm (a corresponding method for the transfer function for the left channel may also be derived):

$$\hat{H}^2_{AR}(k) = \frac{Y(k)}{R(k)} \cdot (1 - |\eta(k)|)$$

where $\eta(k)$ is the coherence of the left and right stereo source signal at frequency index k.

$$\eta(k) = \left\langle \frac{L(k) \cdot R^*(k)}{|L(k)| \cdot |R(k)|} \right\rangle$$

where the expectation is over time.

4. Extract those components of the left and right ECAD source signals which are uncorrelated (orthogonal) and use them to make estimates of the left and right channel responses. In this approach, a common component C(k) in the left and right ECAD sources is removed by adaptive filtering to yield an orthogonal pair of signals, L''(k) and R''(k):

$$R(k) = R''(k) + H_{CR}(k) \cdot C(k)$$

$$L(k) = L''(k) + H_{CL}(K) \cdot c(k)$$

wherein $H_{CL}(k)$ is the transfer function between the common (left and right stereo signals combined, which may be fixed in a recording studio) ECAD signal source and the left ECAD signal source and $H_{CR}(k)$ is the transfer function between the common ECAD source, signal and the right ECAD source.

The orthogonalised signals are used to make the acoustic channel response estimates. For the right stereo channel transfer function the following expression may be used (a corresponding expression for the left stereo channel transfer function may also be obtained):

$$\hat{H}_{AR}(k)=\frac{Y(k)}{R''(k)}=\frac{H_{AR}(K).(R''(k)+H_{CR}(k).C(k))}{R''(k)}+\frac{H_{AL}(k).(L''(k)+H_{CL}(k).C(k))}{R''(k)}+\frac{S(k)}{R''(k)}$$

Most of the terms are long term uncorrelated so we get:

$$\hat{H}_{AR}(k)=\frac{Y(k)}{R''(k)}=\frac{H_{AR}(k).R''(k)}{R''(k)}=H_{AR}(k)$$

the true acoustic channel response.

Thus, the right stereo acoustic channel function, $\hat{H}_{AR}(k)$, may be obtained by dividing the signal received at the microphone by R''(k).

Figure 3 of the accompanying drawings illustrates schematically an example of components which may be used to form L''(jω) and R''(jω). The components include two adaptive filters, 303 and 304, either implemented in the frequency domain, or preferably, the time domain. The coefficients of each FIR adaptive filter are adjusted using LMS or similar, to minimise the total energy in r''(n) and l''(n), respectively, i.e. operate filters in standard system identification mode as in echo cancelling etc.

The right stereo ECAD signal r(n) 301 is fed into

adaptive filter 303 and a combiner 305. The left stereo ECAD signal l(n) 302 is fed into adaptive filter 304 and a combiner 306. The output of adaptive filter 303 is also fed into combiner 306. The output of adaptive filter 304 is also fed into combiner 305. The output of combiner 305 may be fed back via an adaption control path into adaptive filter 304. The output of mixer 306 may be fed back into adaptive filter 303 via an adaption control path. The output of combiner 305 comprises the orthogonal right stereo signal r''(n) 307. The output of combiner 306 comprises the left stereo orthogonal signal l''(n) 308.

Figure 4 of the accompanying drawings illustrates a block diagram representing a specific embodiment of the present invention. Processing components of Fig. 4 may be electronic processors fitted integrally to the in-car device where the speech recognition system is located or, alternatively, may be a stand alone electronic device intended to receive acoustic signals, cancel non-stationary interfering signals and output a filtered acoustic signal to be received by the speech recognition system's microphone.

ECAD sound source 401 (such as the signals output loudspeakers 101 and 102 of Figure 1) may be received directly by a spectral analysis process 404 so that the signal as produced by the ECAD prior to transmission through the in-car acoustic channel 403 may be analysed. The ECAD signal is also received by a spectral analysis process 405 after transmission through acoustic channel 403 so that the signal 401 is in effect simultaneously spectrally analysed

before and after transmission through the acoustic channel 403. The spectral analysis of processes 404 and 405 is preferably carried out at a 16 ms frame rate using a 256 point Fast Fourier Transformer. If user speech 402 (corresponding to wanted speech signal S(jω) 104 of Figure 1) is also present then this acoustic signal too will also be transmitted through the acoustic channel 403 and received by spectral analysis process 405.

The output of spectral analysis processes 404 and 405 are used as inputs to acoustic channel model estimation process 406 which preferably functions in accordance with algorithm 200 described herein above. Acoustic channel model estimation process 406 produces an acoustic channel model 407 which may be used as an input to a spectral subtraction process 408 which also receives the acoustic signal transferred through channel 403.

When the speech recognition system is required, the acoustic channel model 407 is frozen for duration of the speech recognition process. The acoustic channel model 407 is then used to recover the speech signal from the microphone signal by subtracting the estimated spectrum of the ECAD interfering signals contained in the model 407 from the acoustic signals received at the microphone. The spectrally subtracted signal representing the recovered wanted speech 409 is then passed to a pattern matcher process 410 (part of the speech recognition system) which may use recognition feature sets such as Hidden Markov of models 311 in order to match the recovered speech signal 409 to a command which is

recognised by the system. The pattern matcher 409 may then pass on an output signal to trace back and decision process 412 in order that the user's speech command be carried out by the device.

Since the spectral subtraction algorithm is frame rather than sample based, its computational complexity is low. The algorithm's main computation is required for the Fast Fourier Transform, which requires order NlogN computations per frame for each channel. This is typically only about 250k computations per second, which is significantly lower than the order 3N computations per sample required by the simplest form of known adaptive filter technique. For an echo tail length of 32 microseconds, 256 samples, this equates to more than 18 million operations per second.

Figures 5 to 8 of the accompanying diagrams illustrate microphone signal traces before and after the non-stationary interferer signal cancellation for different types of music output by the ECAD at different signal to interference ratios. In order to allow for comparison between an uncancelled signal passed through the acoustic channel and the cancelled signal, test data was constructed by recording speech and interferer signals separately in the same car environment and then adding the two signals. In the examples shown in figures 5 to 8, the interfering music is a stereo signal.

Figures 5A to 5D of the accompanying drawings illustrate microphone traces with and without cancellation in a case where the ECAD outputs pop music at 0dB signal to

interference ratio. In Fig. 5A a signal received at the microphone prior to cancellation is illustrated. In this case, peak segmental speech and interferer levels are the same. This is a highly pessimistic way of estimating signal-to-noise ratio as amplitude variability of speech signal is higher than that of the ECAD music signal output which exceeds the speech for a considerable part of the example. Fig. 5B illustrates a signal resulting from an inverse transformation on the signal of Fig. 5A after spectral subtraction. The interfering signal as shown in Fig. 5B has clearly been reduced. Fig. 5C illustrates a signal representing normalised squared cepstral distances for application of the cancellation algorithm. Fig. 5D illustrates a signal trace for the normalised squared cepstral distances of Fig. 5C after spectral subtraction. Comparing the traces illustrated in Fig. 5C and 5D, it can be seen that the recovered speech cepstral are less distorted than with the interferer.

Figures 6A to 6D of the accompanying drawings illustrate microphone traces with and without cancellation in a case where the ECAD outputs pop music at 10 decibel signal to interference ratio. In Fig. 6A a signal received at the microphone prior to cancellation is illustrated. Fig. 6B. illustrates a signal resulting from an inverse transformation on the signal of 6A after spectral subtraction. The interfering signal shown in Fig. 6B has clearly been reduced. Fig. 6C illustrates a signal representing normalised squared cepstral distances for application of the

cancellation algorithm. Fig. 6D illustrates a signal trace for the normalised square cepstral distances of Fig. 6C after spectral subtraction.

Figures 7A to 7D of the accompanying drawings illustrate microphone traces with and without cancellation in a case where the ECAD outputs opera music at 0 decibel signal to interference ratio. In Fig. 7A a signal received at the microphone prior to cancellation is illustrated. Fig. 7B. illustrates a signal resulting from an inverse transformation on the signal of 7A after spectral subtraction. The interfering signal shown in Fig. 7B has clearly been reduced. Fig. 7C illustrates a signal representing normalised squared cepstral distances for application of the cancellation algorithm. Fig. 7D illustrates a signal trace for the normalised square cepstral distances of Fig. 7C after spectral subtraction.

Figures 8A to 8D of the accompanying drawings illustrate microphone traces with and without cancellation in a case where the ECAD outputs opera music at 10 decibel signal to interference ratio. In Fig. 8A a signal received at the microphone prior to cancellation is illustrated. Fig. 8B. illustrates a signal resulting from an inverse transformation on the signal of 8A after spectral subtraction. The interfering signal shown in Fig. 8B has clearly been reduced. Fig. 8C. illustrates a signal representing normalised squared cepstral distances for application of the cancellation algorithm. Fig. 8D illustrates a signal trace for the normalised square cepstral distances of Fig. 8C

after spectral subtraction.

## Claims

1. Apparatus for cancellation of one or more non-stationary interfering signals for speech recognition, said apparatus including:

means for receiving an acoustic signal;

means for generating an estimated value of a magnitude spectrum of said non-stationary interfering signals; and

means for subtracting said estimated value from said received acoustic signal to produce a representation of a wanted speech magnitude spectrum.

2. Apparatus according to claim 1, wherein said means for generating estimated value includes processing means configured to estimate a transfer function for an acoustic channel between each source of said non-stationary interfering signals and said means for receiving an acoustic signal.

3. Apparatus according to claim 2, wherein said processing means is configured to estimate transfer functions for said non-stationary interfering signals produced by left and right stereo channel transmissions.

4. Apparatus according to Claim 2 or Claim 3, wherein said estimation of said transfer functions is achieved by said processing means executing an iterative algorithm on a frame-by-frame basis, the frames being constituted by said acoustic signals received during successive time periods.

5. Apparatus according to Claim 4 when dependent upon Claim 3, wherein said processing means is configured to estimate respective magnitudes of said left and right channel interference signals,

said magnitude of left channel interference signal is estimated by subtracting said right channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iteration; and

said magnitude of right channel interference signal is estimated by subtracting said left channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iteration.

6. Apparatus according to Claim 5, wherein said transfer function estimate for said right stereo acoustic channel is determined by dividing said right channel interference magnitude estimate by said interfering signal transmitted from said right acoustic stereo channel; and

said transfer function estimate for said left stereo acoustic channel is determined by dividing said left channel interference magnitude estimate by said interfering signal transmitted from said left acoustic stereo channel.

7. Apparatus according to Claim 6, wherein said right acoustic channel transfer function estimation is performed for a said iteration only if a ratio of total energy of said right acoustic stereo channel interfering signal over total energy of said left acoustic stereo channel interfering signal exceeds a predetermined threshold value; and

said left acoustic channel transfer function estimation is performed for a said iteration only if a ratio of total energy of said left acoustic stereo channel interfering

signal over total energy of said right acoustic stereo channel interfering signal exceeds a predetermined threshold value.

8. Apparatus according to Claim 7, wherein said ratio and threshold comparisons are applied to individual frequency components in spectra of said signals.

9. Apparatus according to Claim 8, wherein said left and right stereo acoustic channel transfer functions are multiplied by $(1-|\eta(k)|)$ where $\eta(k)$ is coherence of said left and right interfering signals at a frequency index k.

10. Apparatus according to Claim 4, wherein said transfer function estimate for said right stereo acoustic channel is obtained using an expression:

$$\hat{H}_{AR}(k)=\frac{Y(k)}{R''(k)}=\frac{H_{AR}(k)\,.R''(k)}{R''(k)}=H_{AR}(k)$$

and said transfer functions estimate for said left stereo acoustic channel is obtained using an expression:

$$\hat{H}_{AL}(k)=\frac{Y(k)}{L''(k)}=\frac{H_{AL}(k)\,.L''(k)}{L''(k)}=H_{AL}(k)$$

wherein $R''(k)=H_{CR}(k).C(k)$, with $C(k)$ being a common component of said left and right stereo channel signals and $H_{CR}(k)$ is a transfer function between common said left and right stereo channel transmissions, and said right stereo channel and $L''(k)=L(k)-H_{CL}(k).C(k)$, where $H_{CL}(k)$ is a transfer function between common said left and right stereo channel transmissions and said left stereo channel signal.

11. Apparatus according to any one of claims 2 to 10, wherein said processing means further comprises means for smoothing said estimated transfer functions in time domain.

12. Apparatus according to claim 11, wherein said means for smoothing in time domain comprises a first order recursive filter.

13. Apparatus according to any one of claims 2 to 12, wherein said processing means further comprises means for smoothing said estimated transfer functions in frequency domain.

14. Apparatus according to Claim 13, wherein said means for smoothing in frequency domain comprises a Finite Impulse Response filter.

15. Apparatus according to any one of claims 2 to 14, wherein said processing means includes means for performing a Fourier Transform.

16. Apparatus according to any of the preceding claims, wherein said non-stationary interfering signals are produced by an electronic acoustic device operating in a vehicle.

17. Apparatus according to any one of the preceding claims, wherein said means for receiving an acoustic signal comprises a microphone.

18. A method of cancellation of one or more non-stationary interfering signals for speech recognition, said method including steps of:

receiving an acoustic signal;

generating an estimated value for a magnitude spectrum of said non-stationary interfering signal; and

subtracting said estimated value from said received acoustic signal to produce a representation of a wanted speech magnitude spectrum.

19. Method according to Claim 18, wherein said step of generating an estimated value comprises estimating a transfer function for an acoustic channel between each source of said non-stationary interfering signals and said means for receiving an acoustic signal.

20. Method according to Claim 19, wherein said transfer functions are estimated for non-stationary interfering signals produced by left and right stereo channel transmissions.

21. Method according to any one of Claims 18 to 20, wherein said steps are executed iteratively on a frame-by-frame basis, the frames being constituted by said acoustic signals received during successive time periods.

22. Method according to Claim 21, when dependent upon Claim 20, wherein said step of estimating a transfer function includes:

estimating a magnitude of said left channel interference signal by subtracting said right channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iteration; and

estimating magnitude of said right channel interference signal by subtracting said left channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iteration.

23. Method according to Claim 22, further comprising steps of:

dividing said right channel interference magnitude estimate by said interfering signal transmitted from said right acoustic stereo channel; and

dividing said left channel interference magnitude estimated by said interfering signal transmitted from said left acoustic stereo channel.

24. Method according to Claim 23, wherein said step of estimating right acoustic channel transfer function is performed for a said iteration only if a ratio of total energy of said right acoustic stereo channel interfering signal over total energy of said left acoustic stereo channel interfering signal exceeds a predetermined threshold value; and

said step of estimating left acoustic channel transfer function estimate is performed for a said iteration only if a ratio of total energy of said left acoustic stereo channel interfering signal over total energy of said right acoustic stereo channel interfering signal exceeds a predetermined threshold value.

25. Method according to Claim 24, wherein said ratio and threshold comparisons are applied to individual frequency components in spectra of said signals.

26. Method according to Claim 25, wherein said left and right stereo acoustic channel transfer functions are multiplied by $(1-|\eta(k)|)$ where $\eta(k)$ is coherence of said left and right interfering signals at a frequency index k.

27. Method according to Claim 21, wherein said transfer function estimate for said right stereo acoustic channel is obtained using an expression:

$$\hat{H}_{AR}(k) = \frac{Y(k)}{R''(k)} = \frac{H_{AR}(k) \,.\, R''(k)}{R''(k)} = H_{AR}(k)$$

and said transfer functions estimate for said left stereo acoustic channel is obtained using an expression:

$$\hat{H}_{AL}(k) = \frac{Y(k)}{L''(k)} = \frac{H_{AL}(k) \,.\, L''(k)}{L''(k)} = H_{AL}(k)$$

wherein $R''(k)=H_{CR}(k).C(k)$, with $C(k)$ being a common component of said left and right stereo channel signals and $H_{CR}(k)$ is a transfer function between common said left and right stereo channel transmissions, and said right stereo channel and $L''(k)=L(k)-H_{CL}(k).C(k)$, where $H_{CL}(k)$ is a transfer function between common said left and right stereo channel transmissions and said left stereo channel signal.

28. Method according to any one of Claims 18 to 27, further comprising a step of smoothing said estimated transfer functions in time domain.

29. Method according to any one of Claims 18 to 28, further comprising a step of smoothing said estimated transfer functions in frequency domain.

30. A speech recognition system including apparatus according to any one of claims 1 to 17.

31. An electronic acoustic device including apparatus according to any one of claims 1 to 17.

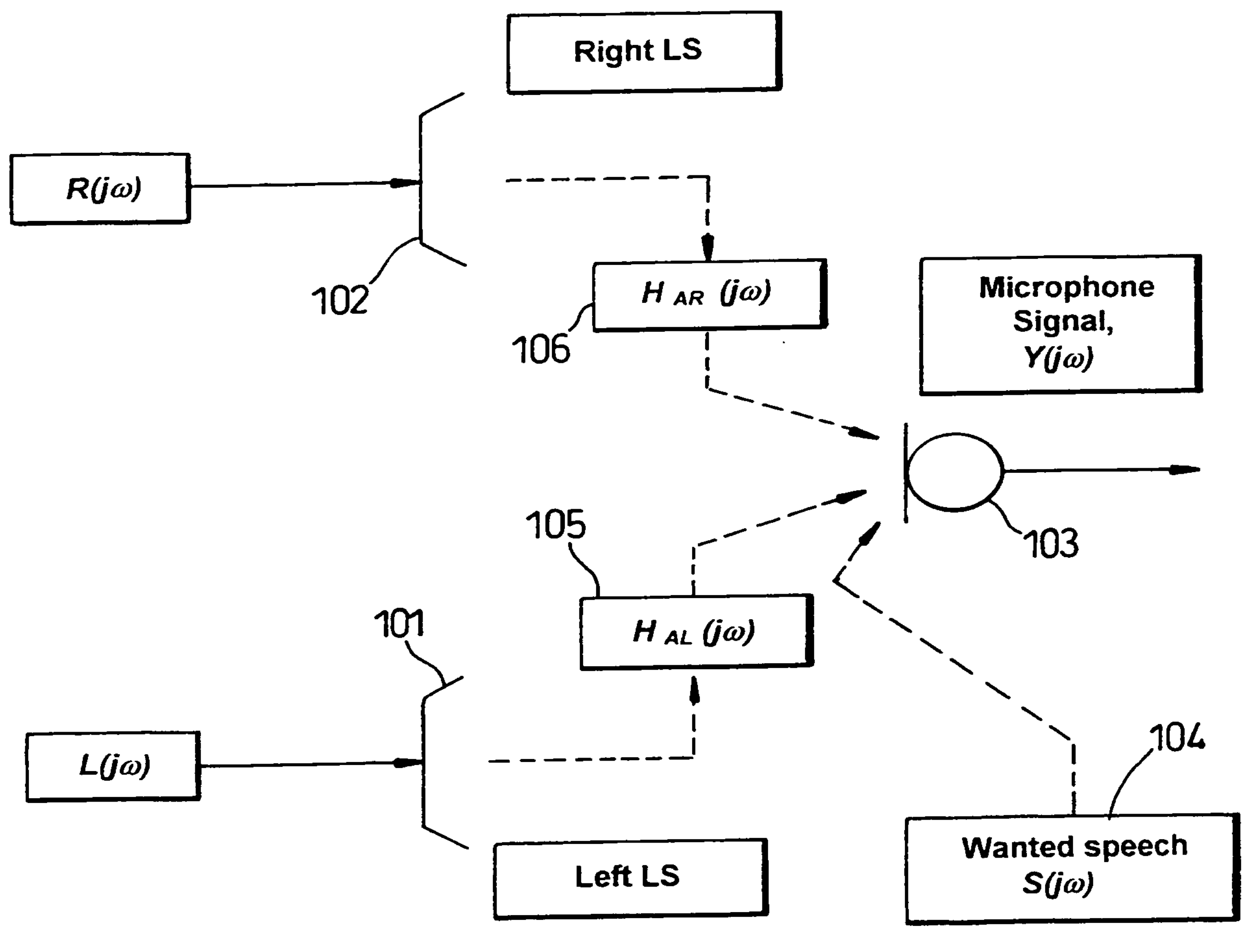
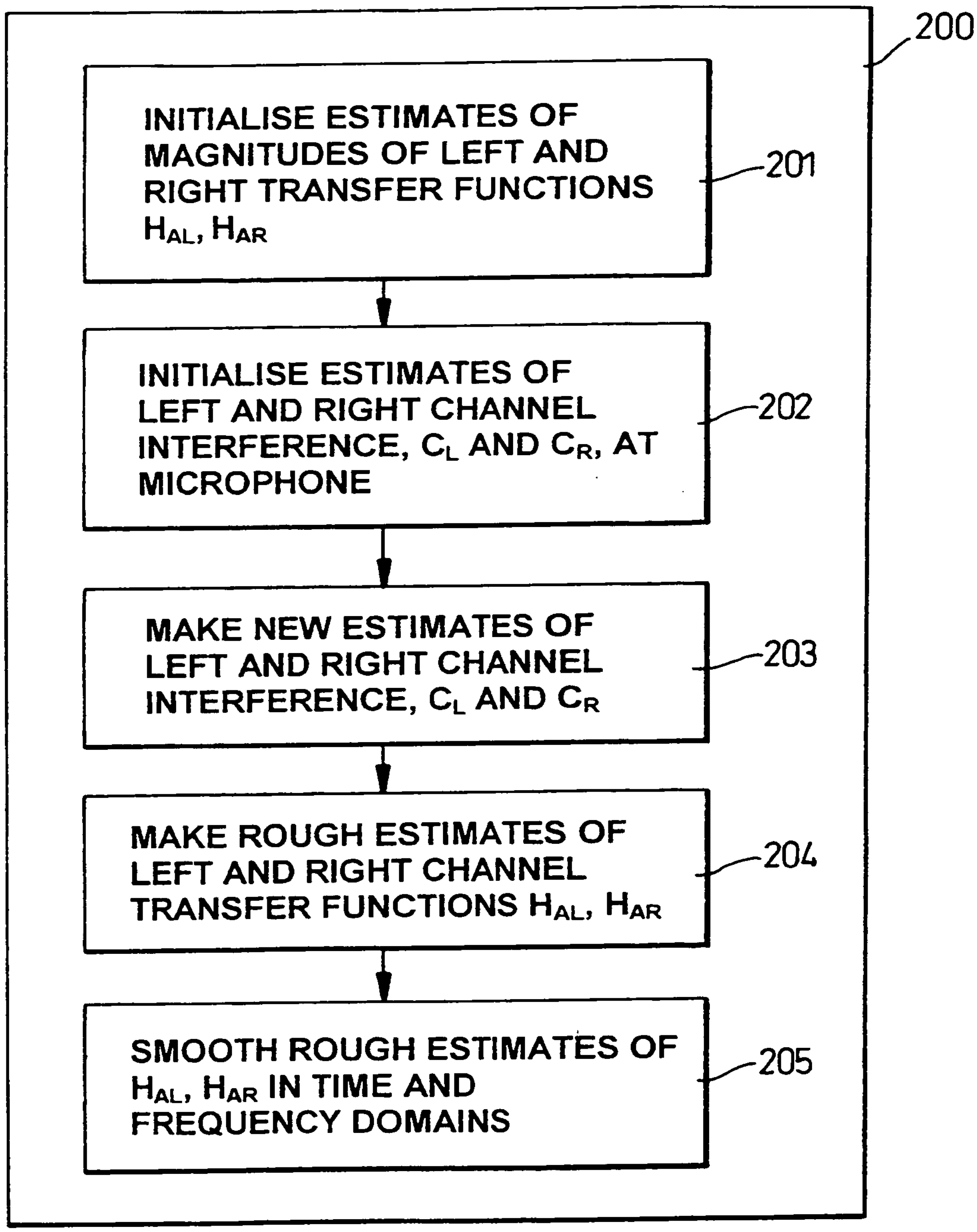

Right LS
R(jω)
102
H AR (jω)
106
Microphone Signal, Y(jω)
103
105
H AL (jω)
101
L(jω)
104
Wanted speech S(jω)
Left LS

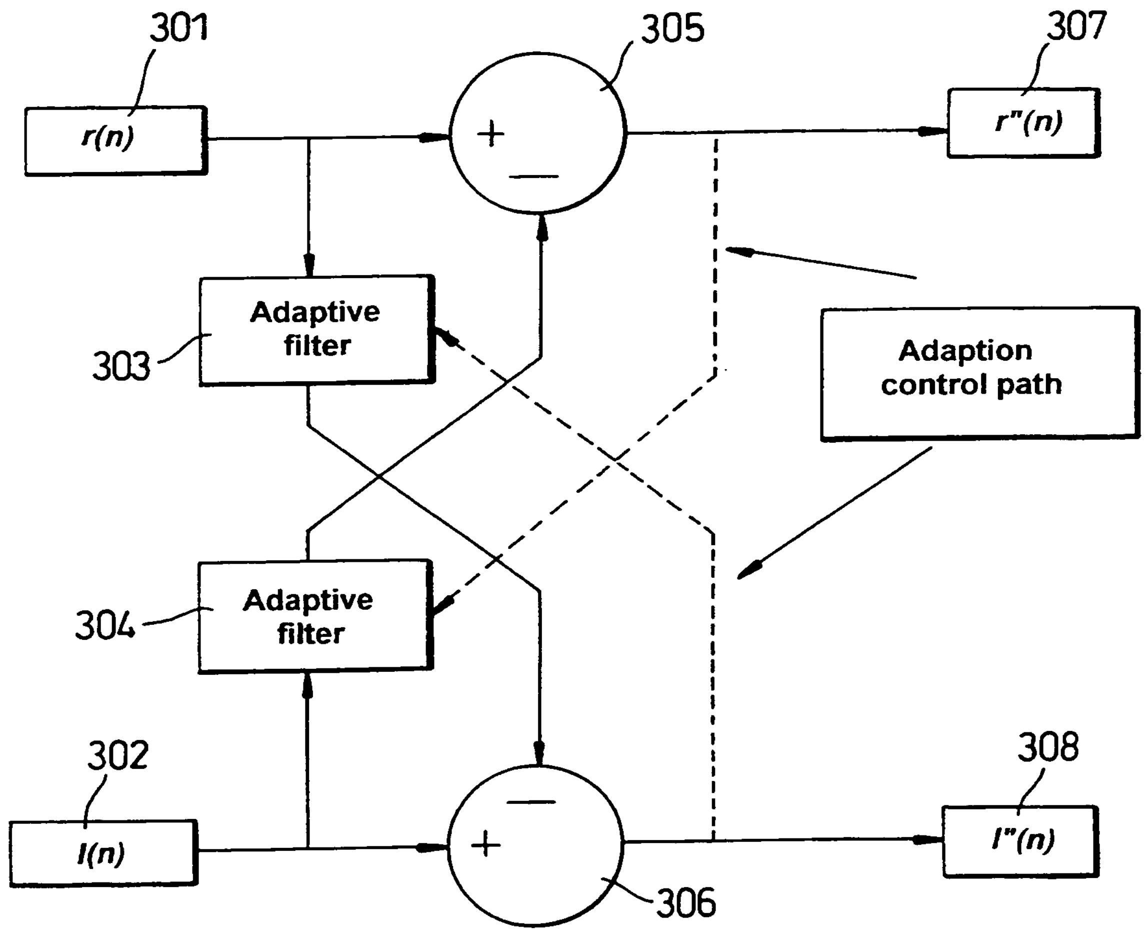
*Fig. 1*

2/8



200
INITIALISE ESTIMATES OF MAGNITUDES OF LEFT AND RIGHT TRANSFER FUNCTIONS $H_{AL}$, $H_{AR}$
201
INITIALISE ESTIMATES OF LEFT AND RIGHT CHANNEL INTERFERENCE, $C_L$ AND $C_R$, AT MICROPHONE
202
MAKE NEW ESTIMATES OF LEFT AND RIGHT CHANNEL INTERFERENCE, $C_L$ AND $C_R$
203
MAKE ROUGH ESTIMATES OF LEFT AND RIGHT CHANNEL TRANSFER FUNCTIONS $H_{AL}$, $H_{AR}$
204
SMOOTH ROUGH ESTIMATES OF $H_{AL}$, $H_{AR}$ IN TIME AND FREQUENCY DOMAINS
205


*Fig. 2*



301
r(n)
305
+
—
307
r"(n)
Adaptive filter
303
Adaption control path
Adaptive filter
304
302
l(n)
—
+
306
308
l"(n)


*Fig. 3*

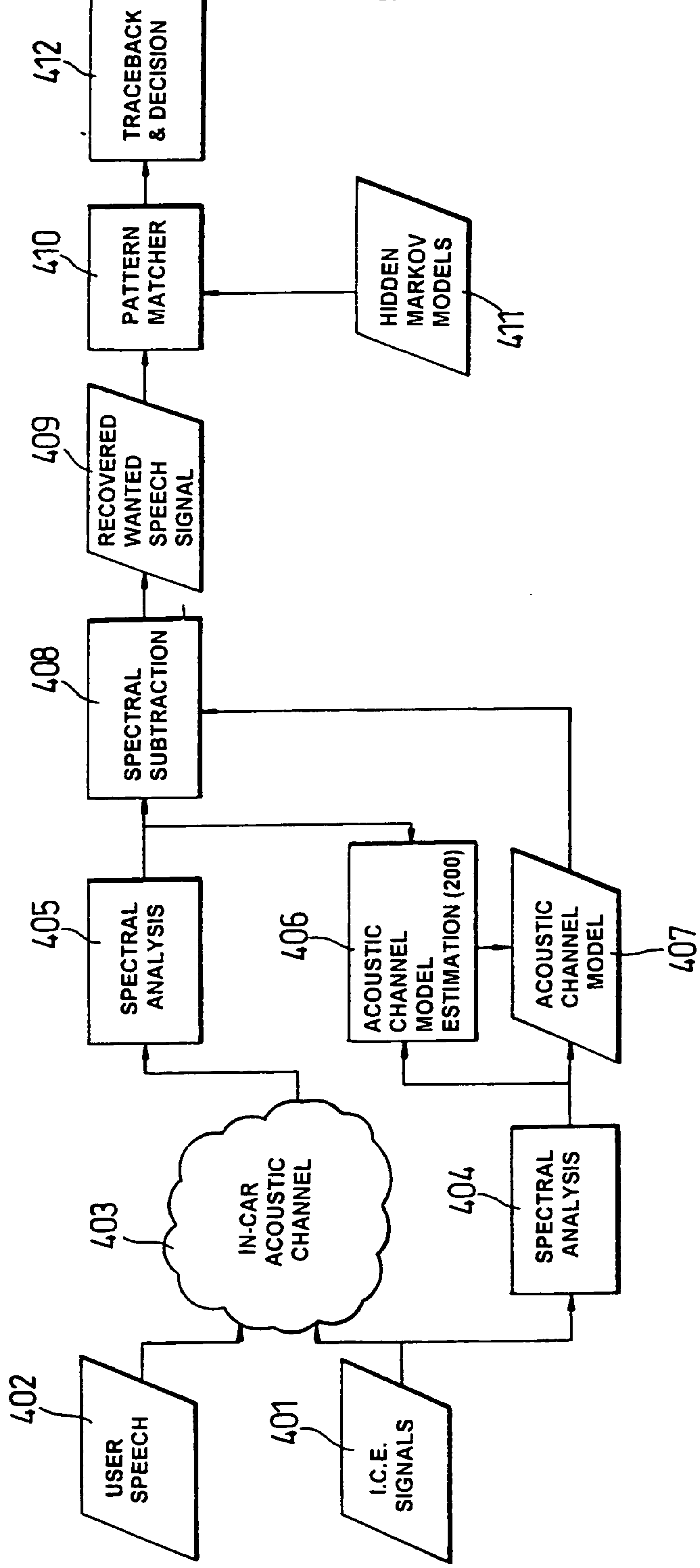

USER SPEECH
402
I.C.E. SIGNALS
401
IN-CAR ACOUSTIC CHANNEL
403
SPECTRAL ANALYSIS
404
SPECTRAL ANALYSIS
405
ACOUSTIC CHANNEL MODEL ESTIMATION (200)
406
ACOUSTIC CHANNEL MODEL
407
SPECTRAL SUBTRACTION
408
RECOVERED WANTED SPEECH SIGNAL
409
PATTERN MATCHER
410
HIDDEN MARKOV MODELS
411
TRACEBACK & DECISION
412

*Fig. 4*

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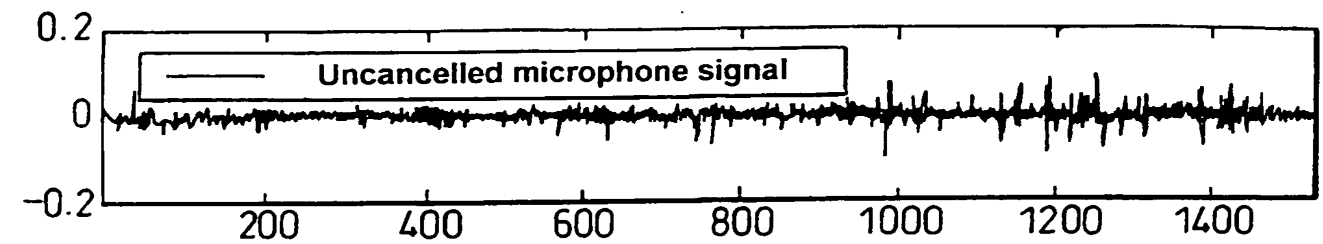


*Fig. 5A*

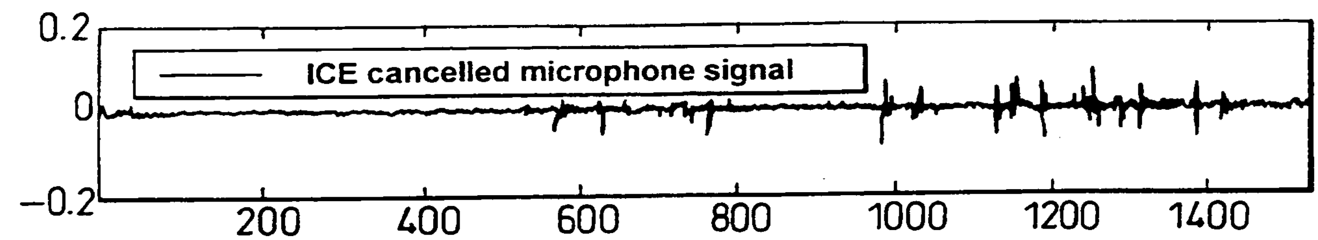


*Fig. 5B*

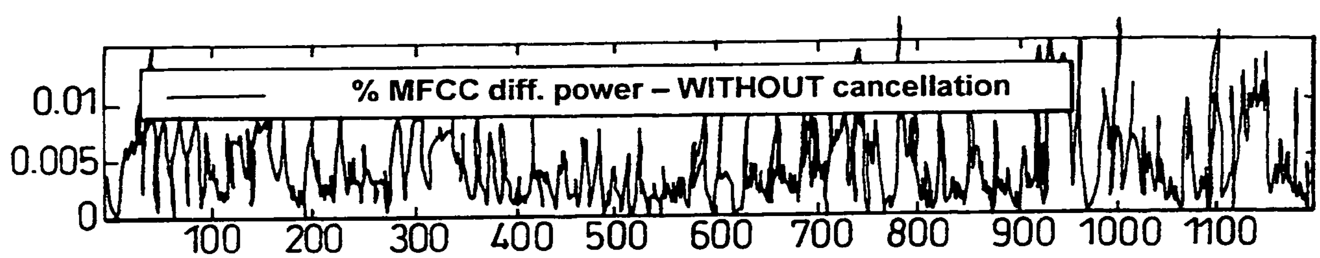


*Fig. 5C*

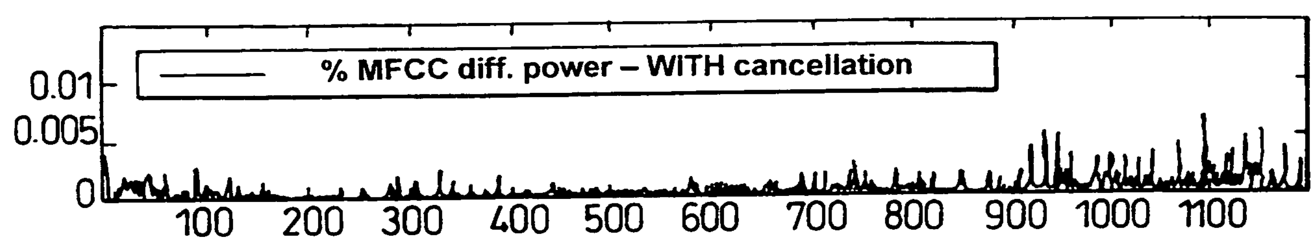


*Fig. 5D*

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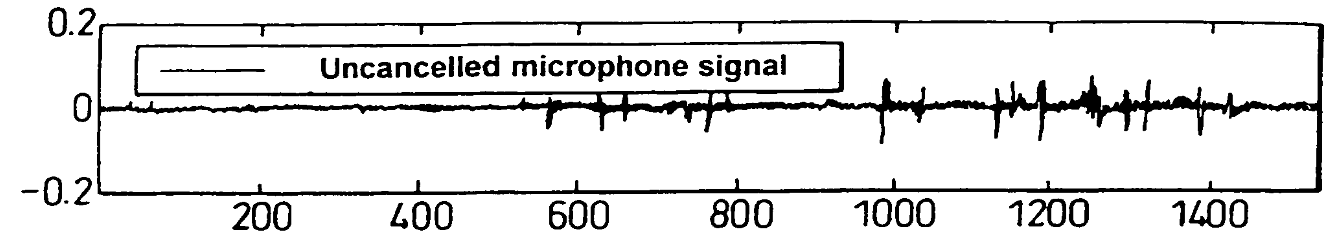



*Fig. 6A*

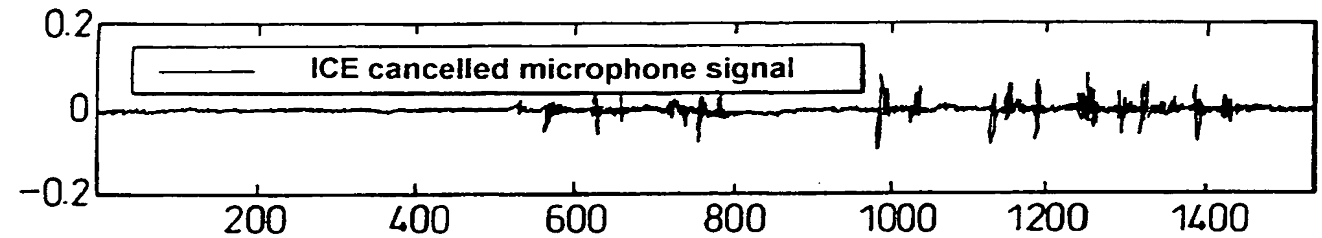



*Fig. 6B*

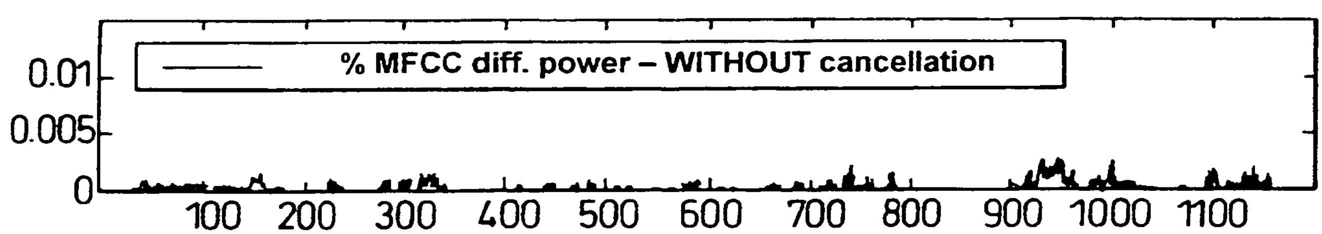



*Fig. 6C*

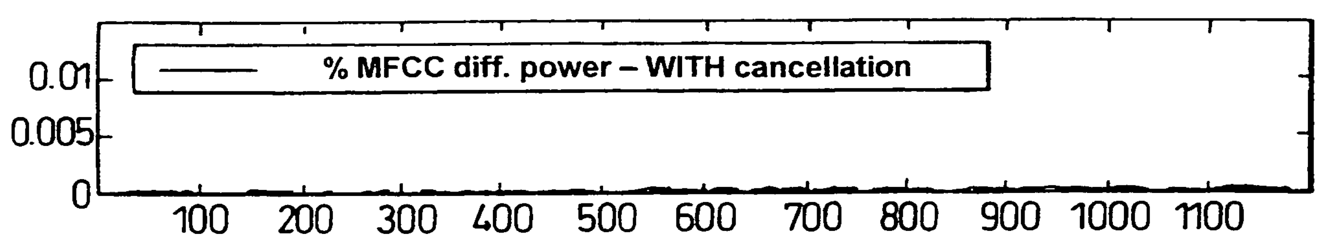



*Fig. 6D*

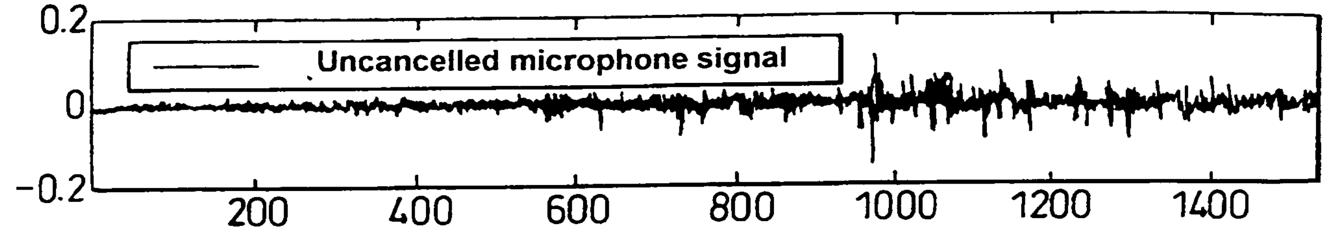



*Fig. 7A*

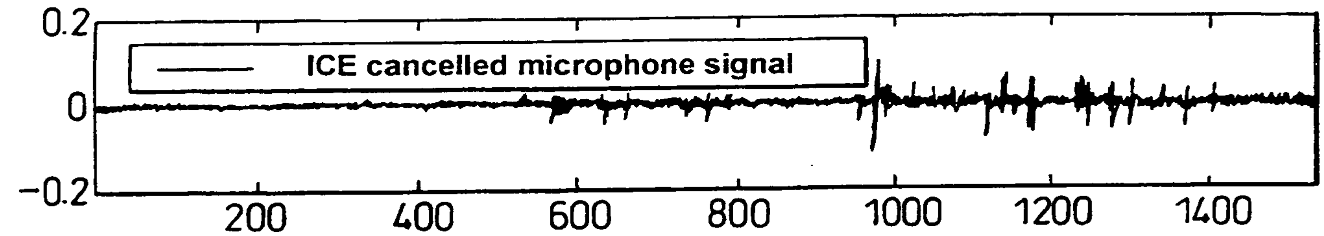



*Fig. 7B*

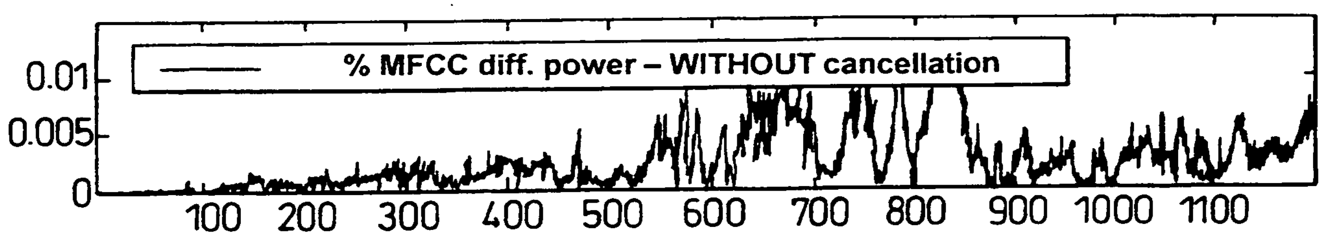



*Fig. 7C*

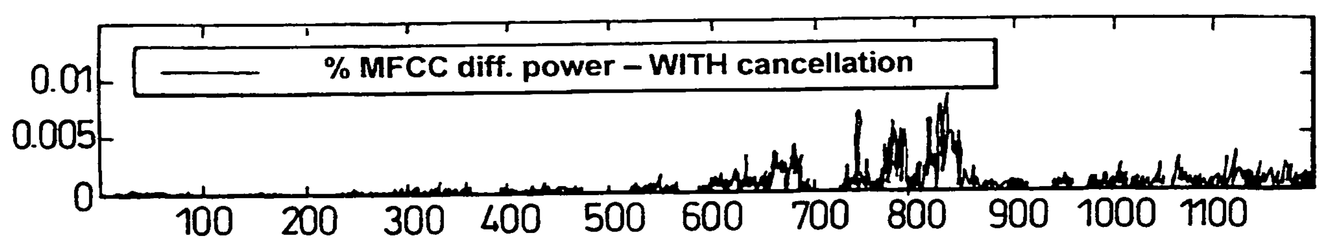



*Fig. 7D*

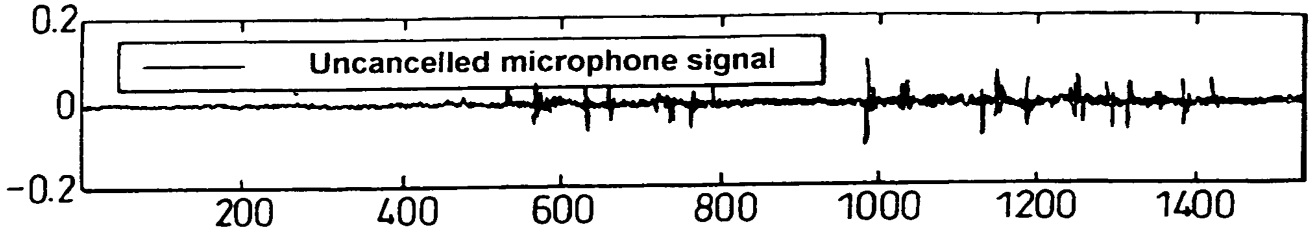



*Fig. 8A*

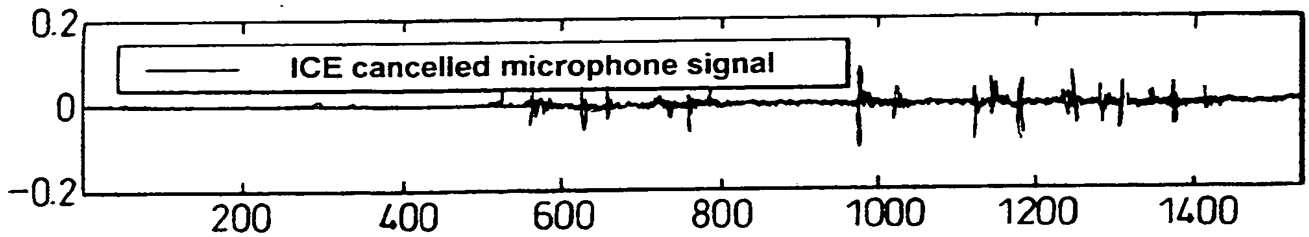



*Fig. 8B*

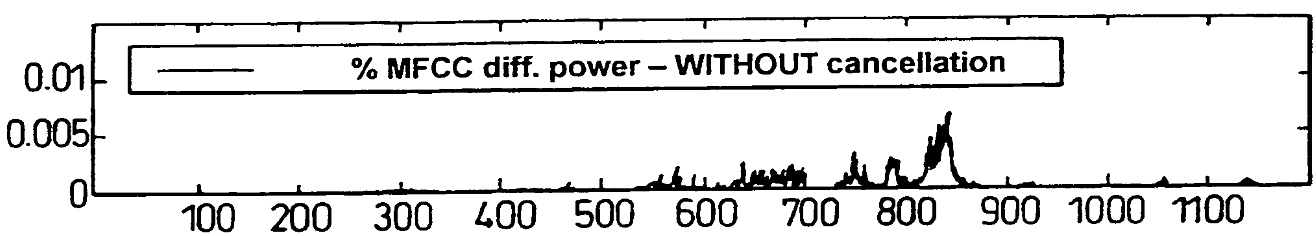



*Fig. 8C*

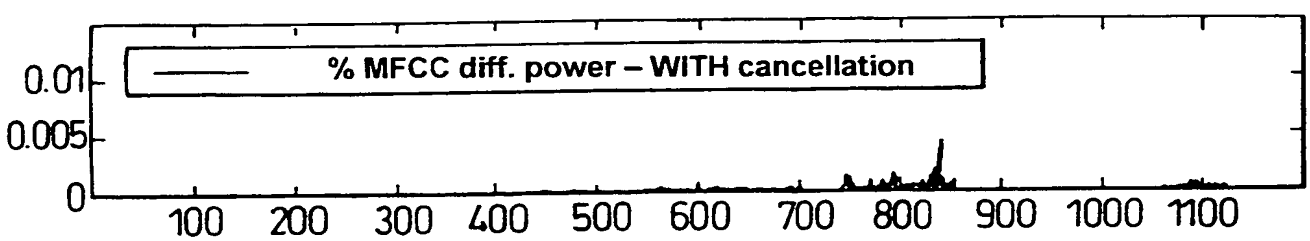



*Fig. 8D*

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01715

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 G10L21/02 G10L15/20

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX, IBM-TDB

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP 0 856 834 A (NIPPON ELECTRIC CO)<br>5 August 1998 (1998-08-05)<br>abstract; claim 1; figure 5<br>--- | 1,2,18,<br>19 |
| A | US 5 864 804 A (KALVERAM HANS)<br>26 January 1999 (1999-01-26)<br>abstract; figure 2<br>column 2, line 1 - line 15<br>column 2, line 61 - line 65<br>----- | 1,2,18,<br>19 |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 15 August 2000 | 22/08/2000 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Van Doremalen, J |

1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/01715

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| EP 0856834 A | 05-08-1998 | JP 2930101 B | 03-08-1999 |
| | | JP 10215194 A | 11-08-1998 |
| | | AU 5278798 A | 06-08-1998 |
| | | CA 2228121 A | 29-07-1998 |
| | | US 5978824 A | 02-11-1999 |
| US 5864804 A | 26-01-1999 | DE 19521258 A | 12-12-1996 |
| | | EP 0747880 A | 11-12-1996 |
| | | JP 9006388 A | 10-01-1997 |

# ~TENT COOPERATION TREAT~

# PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

| Applicant's or agent's file reference<br>BKCD/IJ/ENS7 | FOR FURTHER ACTION | see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below. |
|---|---|---|
| International application No.<br>PCT/GB 00/01715 | International filing date (*day/month/year*)<br>05/05/2000 | (Earliest) Priority Date (*day/month/year*)<br>07/05/1999 |
| Applicant<br>ENSIGMA LIMITED et al. | | |

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readble form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.
   [ ] None of the figures.

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01715

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 G10L21/02 G10L15/20

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX, IBM-TDB

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP 0 856 834 A (NIPPON ELECTRIC CO) 5 August 1998 (1998-08-05) abstract; claim 1; figure 5 | 1,2,18, 19 |
| A | US 5 864 804 A (KALVERAM HANS) 26 January 1999 (1999-01-26) abstract; figure 2 column 2, line 1 - line 15 column 2, line 61 - line 65 | 1,2,18, 19 |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 15 August 2000 | 22/08/2000 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016 | Van Doremalen, J |

# INTER[illegible]ONAL SEARCH REPORT

I[illegible]tion on patent family members

[illegible]onal Application No
PCT/GB 00/01715

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| EP 0856834 A | 05-08-1998 | JP 2930101 B | 03-08-1999 |
| | | JP 10215194 A | 11-08-1998 |
| | | AU 5278798 A | 06-08-1998 |
| | | CA 2228121 A | 29-07-1998 |
| | | US 5978824 A | 02-11-1999 |
| US 5864804 A | 26-01-1999 | DE 19521258 A | 12-12-1996 |
| | | EP 0747880 A | 11-12-1996 |
| | | JP 9006388 A | 10-01-1997 |

1-9-00 /
2-9-00 /

..TENT COOPERATION TREAT

From the INTERNATIONAL SEARCHING AUTHORITY

To:
Wynne-Jones, Lainé & James
Attn. DUNLOP,Brian Kenneth C.
22 Rodney Road
Cheltenham
Gloucestershire, GL50 1JJ
UNITED KINGDOM

# PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

| | |
|---|---|
| | Date of mailing (*day/month/year*) 22/08/2000 |
| Applicant's or agent's file reference BKCD/IJ/ENS7 | **FOR FURTHER ACTION** See paragraphs 1 and 4 below |
| International application No. PCT/GB 00/01715 | International filing date (*day/month/year*) 05/05/2000 |
| Applicant ENSIGMA LIMITED et al. | |

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.
   **Filing of amendments and statement under Article 19:**
   The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

   **When?** The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

   **Where?** Directly to the International Bureau of WIPO
   34, chemin des Colombettes
   1211 Geneva 20, Switzerland
   Fascimile No.: (41-22) 740.14.35

   **For more detailed instructions**, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

   Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

   Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

| Name and mailing address of the International Searching Authority | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL-2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Lucia Van Pinxteren |

# NO..ES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

## INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international pbulication. Furthermore, it should be emphasized that provisional protection is available in some States only.

**What parts of the international application may be amended?**

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

**When?** Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

**Where not to file the amendments?**

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

**How?** Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

**The amendments must be made in the language in which the international application is to be published.**

**What documents must/may accompany the amendments?**

**Letter (Section 205(b)):**

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

**The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.**

## NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

**The following examples illustrate the manner in which amendments must be explained in the accompanying letter:**

1. [Where originally there were 48 claims and after amendment of some claims there are 51]: "Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."
2. [Where originally there were 15 claims and after amendment of all claims there are 11]: "Claims 1 to 15 replaced by amended claims 1 to 11."
3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]: "Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or "Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
4. [Where various kinds of amendments are made]: "Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

**"Statement under article 19(1)" (Rule 46.4)**

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

**It must be in the language in which the international appplication is to be published.**

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

**Consequence if a demand for international preliminary examination has already been filed**

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

**Consequence with regard to translation of the international application for entry into the national phase**

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

# PCT

## REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* BKCD/IJ/ENS7

**Box No. I TITLE OF INVENTION**

Cancellation of non-stationary interfering signals for speech recognition

**Box No. II APPLICANT**

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

Ensigma Limited,
Turing House,
Station Road,
Chepstow. NP6 6PB

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(that is, country)* of nationality: United Kingdom

State *(that is, country)* of residence: United Kingdom

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

**Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)**

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

CAREY, Michael John,
Ensigma Limited,
Turing House,
Station Road,
Chepstow. NP6 6PB

This person is:
☐ applicant only
☒ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: United Kingdom

State *(that is, country)* of residence: United Kingdom

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

**Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE**

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

DUNLOP, Brian Kenneth Charles,
Wynne-Jones, Laine & James,
22 Rodney Road,
Cheltenham,
Glos. GL50 1JJ
United Kingdom

Telephone No. 01242 515807

Facsimile No. 01242 224183

Teleprinter No. 437115 WYNPAT G

☐ Address for correspondence: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

**Continuation of Box No. III F[illegible]R APPLICANT(S) AND/OR (FURTHER) I[illegible]TOR(S)**

*If none of the fo[illegible]ing sub-boxes is used, this sheet should not be i[illegible]uded in the request.*

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

TATTERSALL, Graham David
New House,
Friston,
Saxmundham,
Suffolk. IP17 1PH
United Kingdom

This person is:

- [ ] applicant only
- [x] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: United Kingdom

State *(that is, country)* of residence: United Kingdom

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [x] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [ ] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [ ] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [ ] the United States of America only
- [ ] the States indicated in the Supplemental Box

- [ ] Further applicants and/or (further) inventors are indicated on another continuation sheet.

**Supplemental Box** *If the Supple... Box is not used, this sheet should not be included ... request.*

*1. ... in any of the Boxes, the space is insufficient to furnish all the information: in such case, write "Continuation of Box No. ..." [indicate the number of the Box] and furnish the information in the same manner as required according to the captions of the Box in which the space was insufficient, in particular:*

(i) *if more than two persons are involved as applicants and/or inventors and no "continuation sheet" is available: in such case, write "Continuation of Box No. III" and indicate for each additional person the same type of information as required in Box No. III. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below;*

(ii) *if, in Box No. II or in any of the sub-boxes of Box No. III, the indication "the States indicated in the Supplemental Box" is checked: in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or "Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the applicant(s) involved and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is applicant;*

(iii) *if, in Box No. II or in any of the sub-boxes of Box No. III, the inventor or the inventor/applicant is not inventor for the purposes of all designated States or for the purposes of the United States of America: in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or "Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the inventor(s) and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is inventor;*

(iv) *if, in addition to the agent(s) indicated in Box No. IV, there are further agents: in such case, write "Continuation of Box No. IV" and indicate for each further agent the same type of information as required in Box No. IV;*

(v) *if, in Box No. V, the name of any State (or OAPI) is accompanied by the indication "patent of addition," or "certificate of addition," or if, in Box No. V, the name of the United States of America is accompanied by an indication "continuation" or "continuation-in-part": in such case, write "Continuation of Box No. V" and the name of each State involved (or OAPI), and after the name of each such State (or OAPI), the number of the parent title or parent application and the date of grant of the parent title or filing of the parent application;*

(vi) *if, in Box No. VI, there are more than three earlier applications whose priority is claimed: in such case, write "Continuation of Box No. VI" and indicate for each additional earlier application the same type of information as required in Box No. VI;*

(vii) *if, in Box No. VI, the earlier application is an ARIPO application: in such case, write "Continuation of Box No. VI", specify the number of the item corresponding to that earlier application and indicate at least one country party to the Paris Convention for the Protection of Industrial Property or one Member of the World Trade Organization for which that earlier application was filed.*

*2. If, with regard to the precautionary designation statement contained in Box No. V, the applicant wishes to exclude any State(s) from the scope of that statement: in such case, write "Designation(s) excluded from precautionary designation statement" and indicate the name or two-letter code of each State so excluded.*

*3. If the applicant claims, in respect of any designated Office, the benefits of provisions of the national law concerning non-prejudicial disclosures or exceptions to lack of novelty: in such case, write "Statement concerning non-prejudicial disclosures or exceptions to lack of novelty" and furnish that statement below.*

Continuation of Box IV

Additional Agents:

NEWELL, William Joseph
LAINE, Simon James
JAMES, Michael John Gwynne

all of

Wynne-Jones, Laine & James
22 Rodney Road
Cheltenham
Gloucestershire GL50 1JJ
United Kingdom

Telephone: 01242 515807
Facsimile: 01242 224183
Telex: 437115 WYNPAT G

**Box No. VI PRIORITY CLA[illegible]** ☐ Further priority c[illegible] [illegible]e indicated in the Supplemental Box.

| Filing date of earlier application *(day/month/year)* | [illegible]umber of earlier application | Where earlier application is: national application: country | regional application:* regional Office | international application: receiving Office |
|---|---|---|---|---|
| item (1) 7 May 1999 | 9910448.1 | GB | | |
| item (2) | | | | |
| item (3) | | | | |

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s): (1)

* *Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

**Box No. VII INTERNATIONAL SEARCHING AUTHORITY**

**Choice of International Searching Authority (ISA)** *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used)*:

ISA /

**Request to use results of earlier search; reference to that search** *(if an earlier search has been carried out by or requested from the International Searching Authority)*:

Date *(day/month/year)* Number Country *(or regional Office)*

**Box No. VIII CHECK LIST; LANGUAGE OF FILING**

This international application contains the following number of sheets:

| | |
|---|---|
| request | : 5 |
| description (excluding sequence listing part) | : 29 |
| claims | : 7 |
| abstract | : 1 |
| drawings | : 8 |
| sequence listing part of description | : |
| **Total number of sheets** | : 50 |

This international application is accompanied by the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☐ other *(specify)*:

Figure of the drawings which should accompany the abstract: 4

Language of filing of the international application: English

**Box No. IX SIGNATURE OF APPLICANT OR AGENT**

*Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).*

JAMES, Michael John Gwynne (Representative)

For receiving Office use only

1. Date of actual receipt of the purported international application:
2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA /
6. ☐ Transmittal of search copy delayed until search fee is paid.

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

**Box No. V DESIGNATION OF STATES**

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

**Regional Patent**

☒ **AP** **ARIPO Patent**: **GH** Ghana, **GM** Gambia, **KE** Kenya, **LS** Lesotho, **MW** Malawi, **SD** Sudan, **SL** Sierra Leone, **SZ** Swaziland, **TZ** United Republic of Tanzania, **UG** Uganda, **ZW** Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT

☒ **EA** **Eurasian Patent**: **AM** Armenia, **AZ** Azerbaijan, **BY** Belarus, **KG** Kyrgyzstan, **KZ** Kazakhstan, **MD** Republic of Moldova, **RU** Russian Federation, **TJ** Tajikistan, **TM** Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

☒ **EP** **European Patent**: **AT** Austria, **BE** Belgium, **CH and LI** Switzerland and Liechtenstein, **CY** Cyprus, **DE** Germany, **DK** Denmark, **ES** Spain, **FI** Finland, **FR** France, **GB** United Kingdom, **GR** Greece, **IE** Ireland, **IT** Italy, **LU** Luxembourg, **MC** Monaco, **NL** Netherlands, **PT** Portugal, **SE** Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT

☒ **OA** **OAPI Patent**: **BF** Burkina Faso, **BJ** Benin, **CF** Central African Republic, **CG** Congo, **CI** Côte d'Ivoire, **CM** Cameroon, **GA** Gabon, **GN** Guinea, **GW** Guinea-Bissau, **ML** Mali, **MR** Mauritania, **NE** Niger, **SN** Senegal, **TD** Chad, **TG** Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* ..........

**National Patent** *(if other kind of protection or treatment desired, specify on dotted line)*

☒ **AE** United Arab Emirates
☒ **AL** Albania ..........
☒ **AM** Armenia ..........
☒ **AT** Austria ..........
☒ **AU** Australia ..........
☒ **AZ** Azerbaijan
☒ **BA** Bosnia and Herzegovina ..........
☒ **BB** Barbados
☒ **BG** Bulgaria ..........
☒ **BR** Brazil ..........
☒ **BY** Belarus ..........
☒ **CA** Canada
☒ **CH and LI** Switzerland and Liechtenstein
☒ **CN** China ..........
☒ **CR** Costa Rica ..........
☒ **CU** Cuba ..........
☒ **CZ** Czech Republic ..........
☒ **DE** Germany ..........
☒ **DK** Denmark ..........
☒ **DM** Dominica
☒ **EE** Estonia ..........
☒ **ES** Spain ..........
☒ **FI** Finland ..........
☒ **GB** United Kingdom
☒ **GD** Grenada
☒ **GE** Georgia ..........
☒ **GH** Ghana ..........
☒ **GM** Gambia
☒ **HR** Croatia ..........
☒ **HU** Hungary ..........
☒ **ID** Indonesia
☒ **IL** Israel ..........
☒ **IN** India ..........
☒ **IS** Iceland
☒ **JP** Japan ..........
☒ **KE** Kenya ..........
☒ **KG** Kyrgyzstan ..........
☒ **KP** Democratic People's Republic of Korea ..........
☒ **KR** Republic of Korea ..........
☒ **KZ** Kazakhstan ..........
☒ **LC** Saint Lucia
☒ **LK** Sri Lanka
☒ **LR** Liberia
☒ **LS** Lesotho ..........
☒ **LT** Lithuania
☒ **LU** Luxembourg
☒ **LV** Latvia
☒ **MA** Morocco ..........
☒ **MD** Republic of Moldova ..........
☒ **MG** Madagascar ..........
☒ **MK** The former Yugoslav Republic of Macedonia ..........
☒ **MN** Mongolia
☒ **MW** Malawi ..........
☒ **MX** Mexico ..........
☒ **NO** Norway
☒ **NZ** New Zealand ..........
☒ **PL** Poland ..........
☒ **PT** Portugal ..........
☒ **RO** Romania
☒ **RU** Russian Federation ..........
☒ **SD** Sudan
☒ **SE** Sweden
☒ **SG** Singapore
☒ **SI** Slovenia ..........
☒ **SK** Slovakia ..........
☒ **SL** Sierra Leone ..........
☒ **TJ** Tajikistan ..........
☒ **TM** Turkmenistan ..........
☒ **TR** Turkey ..........
☒ **TT** Trinidad and Tobago ..........
☒ **TZ** United Republic of Tanzania
☒ **UA** Ukraine ..........
☒ **UG** Uganda ..........
☒ **US** United States of America ..........
☒ **UZ** Uzbekistan ..........
☒ **VN** Viet Nam ..........
☒ **YU** Yugoslavia ..........
☒ **ZA** South Africa ..........
☒ **ZW** Zimbabwe ..........

Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet:

☒ ..AG..........
☒ ..DZ..........

**Precautionary Designation Statement**: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation (including fees) must reach the receiving Office within the 15-month time limit.)*

**PCT** WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G10L 21/02, 15/20 — A1

(11) International Publication Number: WO 00/68936

(43) International Publication Date: 16 November 2000 (16.11.00)

(21) International Application Number: PCT/GB00/01715

(22) International Filing Date: 5 May 2000 (05.05.00)

(30) Priority Data:
9910448.1 7 May 1999 (07.05.99) GB

(71) Applicant (*for all designated States except US*): IMAGINATION TECHNOLOGIES LIMITED [GB/GB]; Home Park Estate, Kings Langley, Hertfordshire WD4 8LZ (GB).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): CAREY, Michael, John [GB/GB]; Ensigma Limited, Turing House, Station Road, Chepstow NP6 6PB (GB). TATTERSALL, Graham, David [GB/GB]; New House, Friston, Saxmundham, Suffolk IP17 1PH (GB).

(74) Agents: DUNLOP, Brian, Kenneth, Charles et al.; Wynne-Jones, Laine & James, 22 Rodney Road, Cheltenham, Gloucestershire GL50 1JJ (GB).

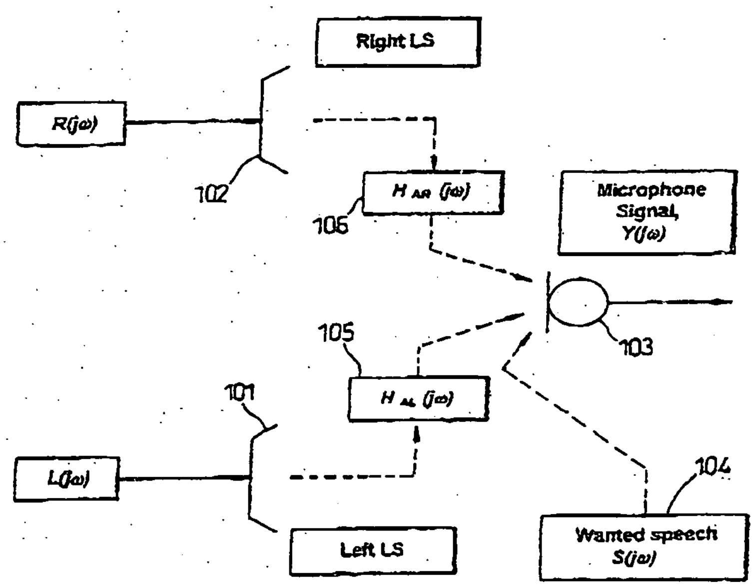
(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published**
*With international search report.*

(54) Title: CANCELLATION OF NON-STATIONARY INTERFERING SIGNALS FOR SPEECH RECOGNITION

(57) Abstract

System for cancellation of non-stationary interfering signals, particularly for use for mitigating effects of such interferers produced by in-car entertainment (ECAD) devices for speech recognition applications. The system spectrally analyses signals output by the ECAD before and after they are passed through an in-car acoustic channel. A model of the acoustic channel is built by the system's algorithm. For speech recognition the model is spectrally subtracted from a signal received at a microphone in order to recover a wanted speech signal. The acoustic channel model is built by estimating frequency domain acoustic transfer functions between each loudspeaker used by the ECAD and the microphone.



PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

DUNLOP,Brian Kenneth C.
Wynne-Jones, Lainé & James
22 Rodney Road
Cheltenham
Gloucestershire, GL50 1JJ
GRANDE BRETAGNE

# PCT

## NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

| | |
|---|---|
| Date of mailing *(day/month/year)* | 20.08.2001 |
| Applicant's or agent's file reference<br>BKCD/IJ/ENS.7 PCT | **IMPORTANT NOTIFICATION** |

| International application No. | International filing date *(day/month/year)* | Priority date *(day/month/year)* |
|---|---|---|
| PCT/GB00/01715 | 05/05/2000 | 07/05/1999 |

Applicant
IMAGINATION TECHNOLOGIES LIMITED et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

| Name and mailing address of the IPEA/ | Authorized officer |
|---|---|
| European Patent Office<br>D-80298 Munich<br>Tel. +49 89 2399 - 0 Tx: 523656 epmu d<br>Fax: +49 89 2399 - 4465 | Corcos, E<br><br>Tel.+49 89 2399-7418 |



27-9-01 23-8-01
7 10-01

# PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

| Applicant's or agent's file reference<br>BKCD/IJ/ENS.7 PCT | FOR FURTHER ACTION | See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416) |
|---|---|---|
| International application No.<br>PCT/GB00/01715 | International filing date *(day/month/year)*<br>05/05/2000 | Priority date *(day/month/year)*<br>07/05/1999 |
| International Patent Classification (IPC) or national classification and IPC<br>G10L21/02 | | |
| Applicant<br>IMAGINATION TECHNOLOGIES LIMITED et al. | | |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☒ Certain defects in the international application
   VIII ☐ Certain observations on the international application

| Date of submission of the demand | Date of completion of this report |
|---|---|
| 05/12/2000 | 20.08.2001 |
| Name and mailing address of the international preliminary examining authority:<br>European Patent Office<br>D-80298 Munich<br>Tel. +49 89 2399 - 0 Tx: 523656 epmu d<br>Fax: +49 89 2399 - 4465 | Authorized officer<br>Greiser, N<br>Telephone No. +49 89 2399 7402 |

**INTERNATIONAL PRELIMINARY EXAMINATION REPORT**

International application No. PCT/GB00/01715

**I. Basis of the report**

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

   **Description, pages:**

   1-29 as originally filed

   **Claims, No.:**

   1-31 as originally filed

   **Drawings, sheets:**

   1/8-8/8 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   ☐ the language of publication of the international application (under Rule 48.3(b)).
   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readable form.
   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:

**INTERNATIONAL PRELIMINARY EXAMINATION REPORT**

International application No. PCT/GB00/01715

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

*(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

6. Additional observations, if necessary:

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

| | | | |
|---|---|---|---|
| Novelty (N) | Yes: | Claims | 1-31 |
| | No: | Claims | |
| Inventive step (IS) | Yes: | Claims | 2-17;19-29 |
| | No: | Claims | 1,18,30-31 |
| Industrial applicability (IA) | Yes: | Claims | 1-31 |
| | No: | Claims | |

2. Citations and explanations
**see separate sheet**

**VII. Certain defects in the international application**

The following defects in the form or contents of the international application have been noted:
**see separate sheet**

**INTERNATIONAL PRELIMINARY EXAMINATION REPORT - SEPARATE SHEET** International application No. PCT/GB00/01715

To Section V:

1. Claim 1 does not meet the requirement of Article 33(3) PCT for the following reason:

   Maintaining performance in the presence of interfering signals is a well known problem associated with speech recognizers. In the prior art, adaptive filters are known to tackle the above problem.

   Document D1= US-A-4630304 (introduced by the International Preliminary Examining Authority; a copy is enclosed), for example, discloses an apparatus for cancellation of quasi-stationary interfering signals whereby said apparatus includes (see col. 3, l. 36-61; fig. 1):
   - means for receiving an acoustic signal;
   - means for generating an estimated value of a magnitudes spectrum of said quasi-stationary interfering signals (see col. 3, 53-57); and
   - means for subtracting said estimated value from said received acoustic signal to produce a representation of a wanted speech magnitudes spectrum (see col. 3, l. 58-61).

   In an attempt to overcome the problem of non-stationary interfering signals, it would readily occur to a skilled person to employ the above apparatus for cancellation of interfering signals. As a result, the subject-matter of claim 1 would be obvious to the skilled person and, hence, claim 1 does not involve an inventive step.

2. Claim 18 claims a method of cancellation of one or more non-stationary interfering signals for speech recognition. Since method claim 18 corresponds to apparatus claim 1, the objection of lack of inventive step raised against claim 1 applies to claim 18 as well. Moreover, claims 30-31 as far as dependent upon claim 1 are not inventive.

3. Claims 2-17 and 19-29 are new and appear to involve an inventive step.

**INTERNATIONAL PRELIMINARY EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/GB00/01715

To Section VII:

4. Document D1 discloses background art which is not identified in the description; furthermore, the relevant prior art disclosed therein is not discussed (Rule 5.1(a)(ii) PCT).

*The demand must be filed directly with ... ætent International Preliminary Examining Auth... two or more Authorities are competent, with the one chosen by the applicant. ... ul name or two-letter code of that Authority may be ... ...d by the applicant on the line below:*

IPEA: ______________________

# PCT

**CHAPTER II**

## DEMAND

under Article 31 of the Patent Cooperation Treaty:
The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty and hereby elects all eligible States (except where otherwise indicated).

| For International Preliminary Examining Authority use only | |
|---|---|
| Identification of IPEA | Date of receipt of DEMAND |

| Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION | | Applicant's or agent's file reference BKCD/IRJ/ENS.7 PCT |
|---|---|---|
| International application No. PCT/GB00/01715 | International filing date *(day/month/year)* 05/05/2000 | (Earliest) Priority date *(day/month/year)* 07/05/1999 |

Title of invention
Cancellation of Non-Stationary Interfering Signals for Speech Recognition

**Box No. II APPLICANT(S)**

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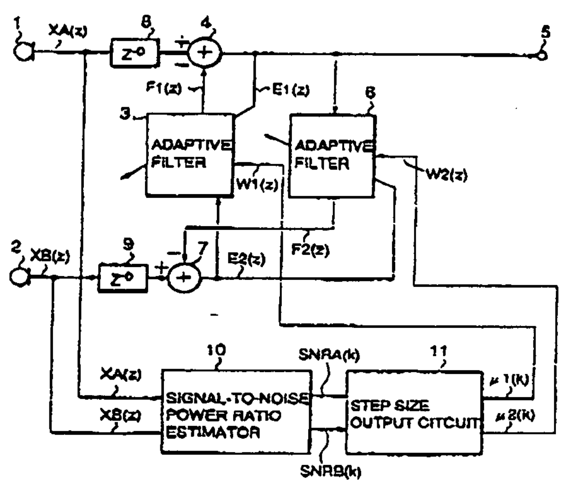
(54) **Noise canceler**

(57) A noise canceler of the present invention includes a signal-to-noise power ratio estimator to which a main signal and a reference signal are input. The estimator 10 estimates the sinal-to-noise power ratio of the main signal from the mean power of a desired signal contained in the main siganl and a mean power of a noise signal also contained in the main signal. In addition, the estimator estimates the signal-to-noise power ratio of the reference signal from the mean power of a desired signal contained in the reference signal and the mean power of a noise singal also contained in the reference signal. An adptive filter for estimating the noise signal of the main signal has its step size for coefficient updating controlled in accordance with the estimated signal-to-noise power ratio of the noise signal. On the other hand, an adptive filter for estimating the desired signal of the reference signal has its step size for coefficient updating controlled in accordance with the estimated signal-to-noise power ratio of the reference signal. Delay circuits are provided for compensating for a delay ascribable to a power averaging procedure which a signal-to-noise power ratio estimator executes to calculate the estimated siganl-to-noise power ratios.

Fig.1




EP 0 856 834 A2

## Description

The present invention relates to a noise canceler and, more particularly, to a noise canceler for canceling, by use of an adaptive filter, a background noise signal introduced into a speech signal input via a microphone, a handset or the like.

A background noise signal introduced into a speech signal input via, e g., a microphone or a handset is a critical problem when it comes to a narrow band speech coder, speech recognition device and so forth which compress information to a high degree. Noise cancelers for canceling such acoustically superposed noise components include a biinput noise canceler using an adaptive filter and taught in B. Widrow et al. "Adaptive Noise Cancelling: Principles and Applications", PROCEEDINGS OF IEEE, VOL. 63, NO. 12, DECEMBER 1975, pp. 1692-1716 (Document 1 hereinafter).

The noise canceler taught in Document 1 includes an adaptive filter for approximating the impulse response of a noise path along which a noise signal input to a microphone assigned to a reference signal (reference signal microphone hereinafter) to propagate toward a microphone assigned to a main signal (main signal microphone hereinafter). The adaptive filter is capable estimating noise introduced into the main signal microphone. The estimated noise signal is subtracted from a main signal (combination of a desired signal and a noise signal) input to the main signal microphone.

The filter coefficient of the above adaptive filter is corrected by determining a correlation between an error signal produced by subtracting the estimated noise signal from the main signal and a reference signal derived from the reference signal microphone. Typical of an algorithm for such coefficient correction, i.e., a convergence algorithm is "LMS algorithm" describe in Document 1 or "LIM (Learning Identification Method) algorithm" described in IEEE TRANSACTIONS ON AUTOMATIC CONTROL, VOL. 12, NO. 3, 1967, pp. 282-287.

A conventional noise cancellation principle will be described with reference to FIG. 5. As shown, a noise canceler includes a main signal microphone 1, a reference signal microphone 2, an adaptive filter 3, a subtracter 4, and an output terminal 5. A desired signal S(z) spoken by a speaker (signal source) is input to the main signal microphone 1 adjoining the speaker's mouth by way of a path having an acoustic transfer characteristic HA(z); *z* is expressed as:

$$z = \exp(2\pi j/FS) \qquad \text{Eq.(1)}$$

where FG denotes a sampling frequency.

On the other hand, noise N(z) issuing from a noise source is input to the main signal microphone 1 via a path having an acoustic transfer characteristic GA(z). At the same time, the noise N(z) is input to a reference signal microphone 2 remote from the speaker by way of a path having an acoustic transfer characteristic GB(z). The adaptive filter 3 estimates, based on the main signal XA(z) and reference signal XB(z), the acoustic transfer characteristic (noise path) P(z) of an acoustic path along which noise output from the noise source N(z) and then input to the reference signal microphone 2 will propagate to the main signal microphone 1 when the desired signal S(z) is not input.

The acoustic transfer characteristic P(z) to be estimated is produced by:

$$P(z) = GA(z)/GB(z) \qquad \text{Eq.(2)}$$

The adaptive filter 3 therefore constitutes a filter having a transfer characteristic W1(z) identical with the transfer function P(z) and operates to generate an estimated noise signal F1(z) identical with the noise signal contained in the main signal. The subtracter 4 subtracts the estimated noise signal F1(z) output from the filter 3 from the main signal XA(z), thereby producing an output E1(z). When the desired signal S(z) is not input, the output signal E1(z) is expressed as:

$$\begin{aligned} E1(z) &= XA(z) - F1(z) \\ &= XA(z) - W1(z)XB(z) \\ &= GA(z)N(z) - W1(z)GB(z)N(z) \\ &= GA(z)N(z) - \{GA(z)/GB(z)\}GB(z)N(z) \\ &= 0 \end{aligned} \qquad \text{Eq.(3)}$$

In this manner, the adaptive filter 3 is capable of estimating the acoustic transfer characteristic P(z) by updating the coefficient such that the output signal E1(z) is zero when the desired signal S(z) is not contained. The output signal E1(z) is referred to as an error signal because it is representative of an error in the learning operation of the adaptive filter.

After the convergence of the adaptive filter 3, the output signal E1(z) is expressed as:

$$\begin{aligned} E1(z) &= XA(z) - F1(z) \\ &= XA(z) - W1(z)XB(z) \\ &= GA(z)N(z) + HA(z)S(z) - W1(z)GB(z)N(z) + HB(z)S(z) \\ &= GA(z)N(z) + HA(z)S(z) - W1(z)GB(z)N(z) - W1(z)HB(z)S(z) \\ &= HA(z)S(z) - W1(z)HB(z)S(z) \\ &= HA(z)S(z)[1 - \{HB(z)/HA(z)\}W1(z)] \end{aligned} \qquad \text{Eq.(4)}$$

As the Eq.(4) indicates, the output signal E1(z) does not contain any noise signal N(z), i.e., noise has been canceled. However, the problem is that when the reference signal microphone 2 contains the desired signal component S(z), i.e., when the acoustic transfer characteristic HB(z) from the desired signal S(z) to the reference signal microphone 2 is not zero, a signal distortion represented by [1 - {HB(z)/HA(z)}W1(z) ] occurs.

To solve the above problem, an adaptive filter for correcting the signal distortion contained in the output signal S1(z) may be added, as taught in Japanese Patent Laid-Open Publication No. 8-56180. FIG. 6 shows a noise canceler including such an additional adaptive filter. As shown, the noise canceler has an adaptive filter 6 for the above correction and a subtracter 7 in addition to the structural elements shown in FIG. 5. When the main signal XA(z) contains the desired signal S(z) and if noise is absent is of less than certain level, the adaptive filter 6 performs learning such that the output E2(x) of the subtracter 7 decreases. Assuming that the adaptive filter 6 has a transfer characteristic W2(z), then the filter 6 performs the above learning based on, e.g., the LIM scheme such that when N(z) is zero or negligible, E2(z) has the following value:

$$\begin{aligned} E2(z) &= XA(z) - F2(z) \\ &= XA(z) - W2(z)E1(z) \\ &= HA(z)S(z) - W2(z)HA(z)S(z)\ [1 - \{HB(z)/HA(z)\}W1(z)] \\ &= HA(z)S(z) - W2(z)HA(z)S(z) + W2(z)S(z)HB(z)W1(z) \\ &= W2(z)S(z)HB(z)W1(z) - HA(z) + HA(z)S(z) \\ &= 0 \end{aligned} \qquad \text{Eq.(5)}$$

Therefore, the transfer characteristic W2(z) of the adaptive filter 6 is produced by:

$$\begin{aligned} W2(z) &= HA(z)/\{HA(z) - HB(z)W1(z)\} \\ &= 1/[1 - \{HB(z)/HA(z)\}W1(z)] \end{aligned} \qquad \text{Eq.(6)}$$

The output F2(z) of the adaptive filter 6 derived from the learning is expressed as:

$$\begin{aligned} F2(z) &= W2(z)E1(z) \\ &= \{1/[1 - \{HB(z)/HA(z)\}W1(z)]\}\ HA(z)S(z)[1 - HB(z)/HA(z)\}W1(z)] \\ &= HA(z)S(z) \end{aligned} \qquad \text{Eq.(7)}$$

As a result, a desired signal HA(z)S(z) free from signal distortion is output.

As stated above, the conventional noise canceler updates the coefficient of the adaptive filter 3 and learns the acoustic characteristic of noise in sections where the noise signal N(z) is present and the desired signal component S(z) is absent or negligibly small. Further, the noise canceler updates the coefficient of the adaptive filter 4 and learns a signal distortion correction filter in sections where the desired signal component S(z) is present and the noise component N(z) is absent or negligibly small. It is therefore necessary to detect the above sections where the desired signal component S(z) is absent (or little) and the sections where the noise signal component N(z) is absent (or little) and to command the adaptive filters to perform leaning in such sections from the outside.

However, it is, in many cases, difficult to command the adaptive filters to perform learning from the outside in accordance with the level of the desired signal and that of the noise signal, depending on the situation in which the noise canceler is located. With the conventional noise canceler, a sufficient noise canceling ability and a sufficient distortion correction characteristic are not achievable unless adequate learning sections are indicated to each adaptive filter for the learning purpose.

It is therefore an object of the present invention to provide a noise canceler capable of achieving a sufficient noise canceling ability and reducing signal distortion even when adequate learning sections cannot be indicated from the outside.

A noise canceler of the present invention includes a first delay circuit for delaying a main signal containing a desired signal and a noise signal by a preselected period of time to thereby output a delayed main signal. A second delay circuit receives the noise signal as a reference signal and delaying it by the preselected period of time to thereby output a delayed reference signal. A first subtracter subtracts a first estimated noise signal from the delayed main signal to thereby generate a first desired signal output. A second subtracter subtracts a first estimated desired signal from the delayed reference signal to thereby generate a first noise signal output. A first adaptive filter receives the first noise sig-

nal output and adaptively estimates a noise signal contained in the delayed main signal to thereby output the first estimated noise signal. A second adaptive filter receives the first desired signal output and adaptively estimating a desired signal contained in the delayed reference singal to thereby output the first estimated desired signal. A signal-to-noise power ratio estimator receives the main signal and reference signal and calculates desired signal power and noise signal power of the main signal and desired signal power and noise signal power of the reference signal to thereby output an estimated value of a power ratio of the main signal to the noise signal and an estimated value of a power ratio of the reference signal to the noise signal. A step size output circuit receives the estimated values from the signal-to-noise power ratio estimator to thereby output a first and a second step size representative of an amount of correction of a filter coefficient of the first adaptive filter and an amount of correction of a filter coefficient of the second adaptive filter, respectively.

The above and other objects, features and advantages of the present invention will become apparent from the following detailed description taken with the accompanying drawings in which:

FIG. 1 is a block diagram schematically showing a noise canceler embodying the present invention;
FIG. 2 is a block diagram schematically showing a signal-to-noise power ratio estimator included in the embodiment;
FIGS. 3 and 4 are flowcharts demonstrating the operation of a step size output circuit 11 also included in the embodiment;
FIG. 5 shows the principle of a conventional noise canceler; and
FIG. 6 is a block diagram schematically showing a specific configuration of a conventional noise canceler.

Referring to FIG. 1 of the drawings, a noise canceler embodying the present invention is shown. As shown, the noise canceler includes a first microphone 1 for a main signal, a second microphone 2 for a reference signal, an output terminal 5, adaptive filters 3 and 6, subtracters 4 and 7, delay circuits 8 and 9, a signal-to-noise power ratio estimator 10, and a step size output circuit 11. The operation of the adaptive filters 3 and 6 will be described first.

A main signal XA(z) is delayed by the delay circuit 8 by D samples to turn out a delayed main signal $XA(z)Z^{-D}$ where $Z^{-D}$ denotes a delay by D samples. The signal $XA(z)Z^{-D}$ is applied to the subtracter 4. On the other hand, a reference signal XB(z) is delayed by the delay circuit 9 by D samples to turn out a delayed reference signal $XB(z)Z^{-D}$ and then applied to the subtracter 7. The delay by D samples compensates for a delay ascribable to the calculation of a signal-to-noise power ratio to be effected by the signal-to-noise power estimator 10, as will be described later specifically. Because the delays provided at the main signal side of the adaptive filter 3 and the reference signal side of the adaptive filter 6, respectively, are equal, they have no influence on the relation between the main signal and the reference signal. Therefore, let D be assumed to be zero hereinafter.

The adaptive filter 3 operates to estimate a noise signal included in the main signal XA(z) while the adaptive filter 6 operates to estimate a desired signal included in the reference signal XB(z). To allow the filter 3 to estimate the noise signal, the desired signal estimated by the filter 6 is subtracted from the reference signal by the subtracter 7, and the resulting noise signal is input to the filter 3. Likewise, the noise signal estimated by the filter 3 is subtracted from the main signal, and the resulting desired signal is input to the filter 6. For this purpose, the two filters 3 and 6 are cross-coupled, as illustrated.

Assume that the subtracters 4 and 7 produce output signals E1(z) and E2(z), respectively, that the adaptive filter 3 has a transfer characteristic W1(z) and produces an output F1(z), and that the adaptive filter 6 has a transfer characteristic W2(z) and produces an output F2(z). Then, E1(z) and E2(z) are expressed as:

$$\begin{aligned} E1(z) &= XA(z) - F1(z) \\ &= XA(z) - W1(z)E2(z) \end{aligned} \qquad \text{Eq.(8)}$$

$$\begin{aligned} E2(z) &= XB(z) - F2(z) \\ &= XB(z) - W2(z)E1(z) \end{aligned} \qquad \text{Eq.(9)}$$

By using the desired signal S(z), noise N(z) and acoustic transfer characteristics HA(z), HB(z) and GB(z) described with reference to FIG. 5, the main signal XA(z) and reference signal XB(z) are produced by:

$$XA(z) = GA(z)N(z) + HA(z)S(z) \qquad \text{Eq.(10)}$$

$$XB(z) = GB(z)N(z) + HB(z)S(z) \qquad \text{Eq.(11)}$$

The above equations give E1(z) and E2(z), as follows:

$$E1(z) = [1/\{1 - W1(z)W2(z)\}]\ \{HA(z) - W1(z)HB(z)\}S(z) + [1/\{1 - W1(z)W2(z)\}]\ \{GA(z) - W1(z)GB(z)\}N(z) \qquad \text{Eq.(12)}$$

$$E2(z) = [1/\{1 - W1(z)W2(z)\}] \{HB(z) - W1(z)HA(z)\}S(z) + [1/\{1 - W1(z)W2(z)\}] \{GB(z) - W1(z)GA(z)\}N(z) \quad \text{Eq.(13)}$$

Therefore, if the following equations are satisfied:

$$W1(z) = GA(z)/GB(z) \quad \text{Eq.(14)}$$

$$W2(z) = HB(z)/HA(z) \quad \text{Eq.(15)}$$

then, there hold:

$$E1(z) = S(z) \quad \text{Eq.(16)}$$

$$E2(z) = N(z) \quad \text{Eq.(17)}$$

As a result, the output E1(z) of the subtracter 4 is the desired signal from which noise has been cancelled.

Now, for the adaptive filter 3 to estimate a noise signal contained in the main signal accurately, it is necessary to increase the amount of updating of the filter coefficient when the desired signal of the main signal obstructing the estimation is smaller than the noise signal to be estimated. Conversely, when the desired signal of the main signal is greater than the noise signal, it is necessary to reduce the above amount because the signal obstructing the estimation is greater than the noise signal.

On the other hand, for the adaptive filter 6 to estimate the desired signal of the reference signal accurately, it is necessary to increase the amount of updating of the filter coefficient when the noise signal contained in the reference signal obstructing the estimation is smaller than the desired signal. Conversely, when the noise signal of the reference signal is greater than the desired signal, it is necessary to reduce the above amount because the signal obstructing the estimation is greater than the desired signal.

The coefficient of each adaptive filter can be controlled to meet the above requirement if the step size of the learning algorithm of the filter is controlled, as follows.

A method of updating the coefficient will be described, assuming the LIM scheme as a learning algorithm and the adaptive filter 3 by way of example. Assume that the main signal XA(z)is denoted by xa(k) in time domain, that E2(z) input to the filter 3 is denoted by e2(k) in time domain, that F1(z) output from the filter 3 is denoted by f1(k) in time domain, and that E1(z) output from the subtracter 4 is denoted by el(k) in time domain; *k* is an index representative of time.

Assuming that the j-th coefficient of the filter 3 at a time *k* is wlj(k), then an estimated noise signal f1(k) output from the filter 3 is expressed as:

$$f1(k) = \sum_{j=0}^{N-1} \omega 1j(k) \cdot e2(k-j) \quad \text{Eq.(18)}$$

where N denotes the number of taps of the filter 3.

A coefficient wlj(k+1) at a time (k+1) is produced on the basis of an error signal el(k) determined by the subtracter 4:

$$\omega 1j(k+1) = \omega 1j(k) + \frac{\mu 1(k) \cdot e1(k) \cdot e2(k-j)}{\sum_{m=0}^{N-1} e2(k-m)^2} \quad \text{Eq.(19)}$$

where $\mu 1(k)$ is the step size for updating the coefficient of the filter 3.

A greater step size $\mu 1(k)$ promotes rapid convergence because the coefficient is corrected by a greater amount. However, when components obstructing the updating of the coefficient are present, the greater amount of updating is noticeably influenced by such components and increases the residual error. Conversely, a smaller stepwise $\mu 1(k)$ reduces the influence of the above obstructing components and therefore the residual error although it increases the converging time. It follows that a trade-off exists between the "converging time" and the "residual error" in the setting of the step size.

Likewise, as for the filter 6, assume that the reference signal XB(z)is denoted by xb(k) in time domain, that E1(z) input to the filter 6 is denoted by e1(k) in time domain, that F2(z) output from the filter 6 is denoted by f2(k) in time domain, and that E2(z) output from the subtracter 7 is denoted by e2(k) in time domain. Then, an estimated noise signal

f2(k) output from the filter 6 is expressed as:

$$f2(k) = \sum_{j=0}^{N-1} \omega 2j(k) \cdot e1(k-j) \qquad \text{Eq.(20)}$$

A coefficient w2j(k+1) at the time (k+1) is produced on the basis of an error signal e2(k) determined by the subtracter 7:

$$\omega 2j(k+1) = \omega 2j(k) + \frac{\mu 2(k) \cdot e2(k) \cdot e1(k-j)}{\sum_{m=0}^{N-1} e1(k-m)^2} \qquad \text{Eq.(21)}$$

where $\mu 2(k)$ is the step size for updating the coefficient of the filter 6.

As stated above, the coefficient can be variably controlled by controlling the step size of the adaptive filter.

The operation of the signal-to-noise power ratio estimator 10 will be described hereinafter. As shown in FIG. 2, the estimator 10 is made up of adaptive filters 12 and 13, subtracters 14 and 15, power mean circuits 16, 17, 18 and 19, and dividers 20 and 21. The adaptive filters 12 and 13 and subtracters 14 and 15 are cross-coupled in exactly the same manner as in FIG. 1. The difference is that step sizes $\mu 3$ and $\mu 4$ assigned to the adaptive filters 12 and 13, respectively, each is fixed and great enough to promote convergence. For example, when the LIM scheme is used, the step sizes $\mu 3$ and $\mu 4$ are selected to be between about 0.2 and about 0.5. Such relatively great step sizes promote rapid convergence although they will increase the residual error.

Assume that the adaptive filters 12 and 13 both are converged. Then, the filter 12 produces an output f3(k) which is the noise signal contained in the main signal. The subtracter 14 produces an output e3(k) which is the desired signal also contained in the main signal. The power mean circuit 16 squares the output e3(k) of the subtracter 14 so as to determine its time mean and thereby outputs desired signal power PSA(k) particular to the main signal. The power mean circuit 17 squares the output f3(k) of the filter 12 so as to determine its time mean and thereby outputs noise signal power PNA(k) particular to the main signal.

The other filter 13 produces an output f4(k) which is the desired signal contained in the reference signal. The subtracter 15 produces an output e4(k) which is the noise signal also contained in the reference signal. The power mean circuit 19 squares the output e4(k) of the subtracter 15 so as to determine its time mean and thereby outputs noise signal power PNB(k) particular to the reference signal. Likewise, the power mean circuit squares the output f4(k) of the filter 13 so as to determine its time mean and thereby outputs desired signal power PSB(k) particular to the reference signal.

The divider 20 divides the desired signal power PSA(k) output from the power mean circuit 16 by the noise signal power PNA(K) output from the power mean circuit 17. As a result, an estimated signal-to-noise power ratio SNRA(k) of the main signal is output from the divider 20. Likewise, the divider 21 divides the desired signal power PSB(K)output from the power mean circuit 18 by the noise signal power pnb(K) output from the power mean circuit 19. As a result, an estimated signal-to-noise power ratio SNRB(k) of the reference signal is output from the divider 21:

When the averaging operation of the power mean circuits 16-19 is implemented by, e.g., the method of moving average, the calculated power mean values involve a delay of ΔAV dependent on the number of times of averaging with respect to the actual power variation. The illustrative embodiment includes the delay circuits 8 and 9, FIG. 1, in order to compensate for the above delay ΔAV. It is therefore desirable that the delay $Z^{-D}$ of the delay circuits 8 and 9 be equal to ΔAV.

With the above configuration, the signal-to-noise power ratio estimator 10 implements rapid convergence by providing the cross-coupled adaptive filters 12 and 13 with a relatively great step size. The estimator 10 outputs, by use of the converged signals, the estimated signal-to-noise power ratio SNRA(k) of the main signal and the estimated signal-to-noise power ratio SNRB(k) of the reference signal.

Reference will be made to FIGS. 3 and 4 for describing the operation of the step size output circuit 11. First, the estimated SNRA(k) of the main signal output from the signal-to-noise power ratio estimator 10 is input to a monotone decreasing function (step 31). Assuming that f(·) is the monotone decreasing function for SNRA (k), then the output OUT1(k) of the function is produced by (step 32):

$$OUT1(k) = f(SNRA(k)) \qquad \text{Eq.(22)}$$

By use of the above value OUT1(k), the step size $\mu 1(k)$ of the adaptive filter 3 is calculated as:

$$\mu 1(k) = \text{clip}[OUT1(k), \mu 1max, \mu 1min] \quad \text{Eq.(23)}$$

where clip[a, b, c] is a function for setting the maximum value and minimum value and defined as:

$$\text{clip}[a, b, c] = a(c \le a \le b)$$

$$\text{clip}[a, b, c] = b\ (a > b)$$

$$\text{clip}[a, b, c] = c(a < c) \quad \text{Eq.(24)}$$

Limiting the step size by use of the maximum value μ1max and minimum value μ1min is desirable for the stable operation of the adaptive filter. As for the adaptive filter 3, the function value determined by inputting the estimated signal-to-noise power ratio SNRA(k) to the monotone decreasing function is used as a step size, as stated above. It follows that the step size is reduced when the signal-to-noise power ratio is great, or it is increased when the ratio is small (steps 33-36).

The estimated signal-to-noise power ratio of the reference signal is also input to a monotone increasing function (step 41). Assuming that g(·) is the monotone decreasing function for SNRB (k), then the output OUT2(k) of the function is produced by (step 42):

$$OUT2(k) = g(SNR\ B(k)) \quad \text{Eq.(25)}$$

By use of the above value OUT2(k), the step size μ2(k) of the adaptive filter 6 is calculated as:

$$\mu 2(k) = \text{clip}[OUT2(k), \mu 2max, \mu 2min] \quad \text{Eq.(26)}$$

As for the adaptive filter 6, the function value determined by inputting the estimated signal-to-noise power ratio SNRB(k) to the monotone decreasing function is used as a step size, as stated above. It follows that the step size is increased when the signal-to-noise power ratio is great, or it is decreased when the ratio is small (steps 43-46).

As described above, the step size output circuit 11 controls the step size to be fed to the adaptive filter 3 in accordance with the estimated signal-to-noise power ratio SNRA(k) of the main signal. Also, the circuit 11 controls the step size to be fed to the adaptive filter 6 in accordance with the estimated signal-to-noise power ratio SNRB(k) of the reference signal.

Alternatively, an arrangement may be made such that the step sizes μ1(k) and μ2(k) assigned to the adaptive filters 3 and 6, respectively, are compared, and smaller one of them is set to be zero in order to interrupt the learning function of the filter whose step size is determined to be zero. This kind of control successfully reduces interference between the two filters 3 and 6 and thereby promotes more accurate learning.

In summary, it will be seen that the present invention provides a noise canceler capable of estimating the noise signal of a main signal and the noise signal of a reference signal accurately. The noise canceler therefore insures rapid convergence and allows a minimum of signal distortion to occur without resorting to a command customarily input from the outside for commanding the learning operation of filters. These advantages are derived from a unique configuration in which a relation in size between a desired signal, which is an interference signal for an adaptive filter used to estimate the noise signal of the main signal from the estimated signal-to-noise power ratio of the main signal, and the noise signal to be canceled is determined. This relation is used to control a step size to be fed to the adaptive filter. This is also true with an adaptive filter for estimating the desired signal of the reference signal from the estimated signal-to-noise power ratio of the reference signal; the noise signal is an interference signal while the desired signal is a signal to be canceled.

Various modifications will become possible for those skilled in the art after receiving the teachings of the present disclosure without departing from the scope thereof.

## Claims

1. A noise canceler comprising:

   first delaying means for delaying a main signal containing a desired signal and a noise signal by a preselected period of time to thereby output a delayed main signal;
   second delaying means for receiving the noise signal as a reference signal and delaying the reference singal by the preselected period of time to thereby output a delayed reference signal;
   first subtracting means for subtracting a first estimated noise signal from said delayed main signal to thereby

generate a first desired signal output;
second subtracting means for subtracting a first estimated desired signal from said delayed reference signal to thereby generate a first noise signal output;
a first adaptive filter for receiving said first noise signal output and adaptively estimating a noise signal contained in said delayed main signal to thereby output said first estimated noise signal;
a second adaptive filter for receiving said first desired signal output and adaptively estimating a desired signal contained in said delayed reference singal to thereby output said first estimated desired signal;
signal-to-noise power ratio estimating means for receiving said main signal and said reference signal and calculating desired signal power and noise signal power of the main signal and desired signal power and noise signal power of the reference signal to thereby output an estimated value of a power ratio of the main signal to the noise signal and an estimated value of a power ratio of the reference signal to the noise signal; and
step size outputting means for receiving said estimated values from said signal-to-noise power ratio estimating means to thereby output a first and a second step size representative of an amount of correction of a filter coefficient of said first adaptive filter and an amount of correction of a filter coefficient of said second adaptive filter, respectively.

2. A noise canceler as claimed in claim 1, wherein said signal-to-noise power ratio estimating means comprises:

third subtracting means for subtracting a second estimated noise signal from the main signal to thereby generate a second desired signal output;
fourth subtracting means for subtracting a second estimated desired signal from the reference signal to thereby generate a second noise signal output;
a third adaptive filter for receiving said second noise signal output and adaptively estimating a noise signal contained in the main signal to thereby output said second estimated noise signal;
a fourth adaptive filter for receiving said second desired signal output and adaptively estimating a desired signal contained in the reference signal to thereby output a second estimated desired signal;
first power averaging means for receiving said second desired signal output and producing a square mean of said second desired signal output to thereby output desired signal power of the main signal;
second power averaging means for receiving said second estimated noise signal and producing a square mean of said second estimated noise signal to thereby output noise signal power of the main signal;
third power averaging means for receiving said second estimated desired signal and producing a square mean of said second estimated desired signal to thereby output desired signal power of the reference signal;
fourth power averaging means for receiving said second noise signal output and producing a square mean of said second noise signal to thereby output noise signal power of the reference signal;
first dividing means for dividing said desired signal power of the main signal by said noise signa power of the main signal to thereby output an estimated value of a power ratio of the main signal to the noise signla; and
second dividing means for dividing said desired signal power of the reference signal by said noise signal power of the reference signal to thereby output an estimated value of a power ratio of the reference signal to the noise signal.

3. A noise canceler as claimed in claim 1 or 2, wherein said step size outputting means comprises:

means for inputting said estimated value of the power ratio of the main signal to the noise signal to a preselected monotonously increasing function to thereby calculate a first function value; and
means for outputting as said first step size said first function value when said first function value is between a first maximum value and a first minimum value, or outputting said first maximum value when said first function value is greater than said first maximum value, or outputting said first minimum value when said first function value is smaller than said first

minimum value.

4. A noise canceler as claimed in claim 1, 2 or 3, wherein said step size outputting means comprises:

means for inputting said estimated value of the power ratio of the reference signal to the noise signal to a preselected monotonously increasing function to thereby calculate a second function value; and
means for outputting as said second step size said second function value when said second function value is between a second maximum value and a second minimum value, or outputting said second maximum value when said second function value is greater than said second maximum value, or outputting said second mini-

mum value when said second function value is smaller than said second minimum value.

5. A noise canceler as claimed in claim 1 or 2, wherein said step size outputting means comprises:

   means for inputting said estimated value of the power ratio of the main signal to the noise signal to a preselected monotonously increasing function to thereby calculate a first function value;
   means for outputting as said first step size said first function value when said first function value is between a first maximum value and a first minimum value, or outputting said first maximum value when said first function value is greater than said first maximum value, or outputting said first minimum value when said first function value is smaller than said first minimum value;
   means for inputting said estimated value of the power ratio of the reference signal to the noise signal to a preselected monotonously increasing function to thereby calculate a second function value; and
   means for outputting as said second step size said second function value when said second function value is between a second maximum value and a second minimum value, or outputting said second maximum value when said second function value is greater than said second maximum value, or outputting said second minimum value when said second function value is smaller than said second minimum value;
   wherein one of said first and second step sizes smaller than the other is set to be zero.

6. A noise canceler as claimed in claim 1, 2, 3, 4 or 5, wherein the preselected period of time assigned to said first and second delaying means is equal to a delay ascribable to calculation of said estimated value of the power ratio of the main signal to the noise signal and said estimated value of the power ratio of the reference signal to the noise signal executed by said signal-to-noise power ratio estimating means.

Fig.1

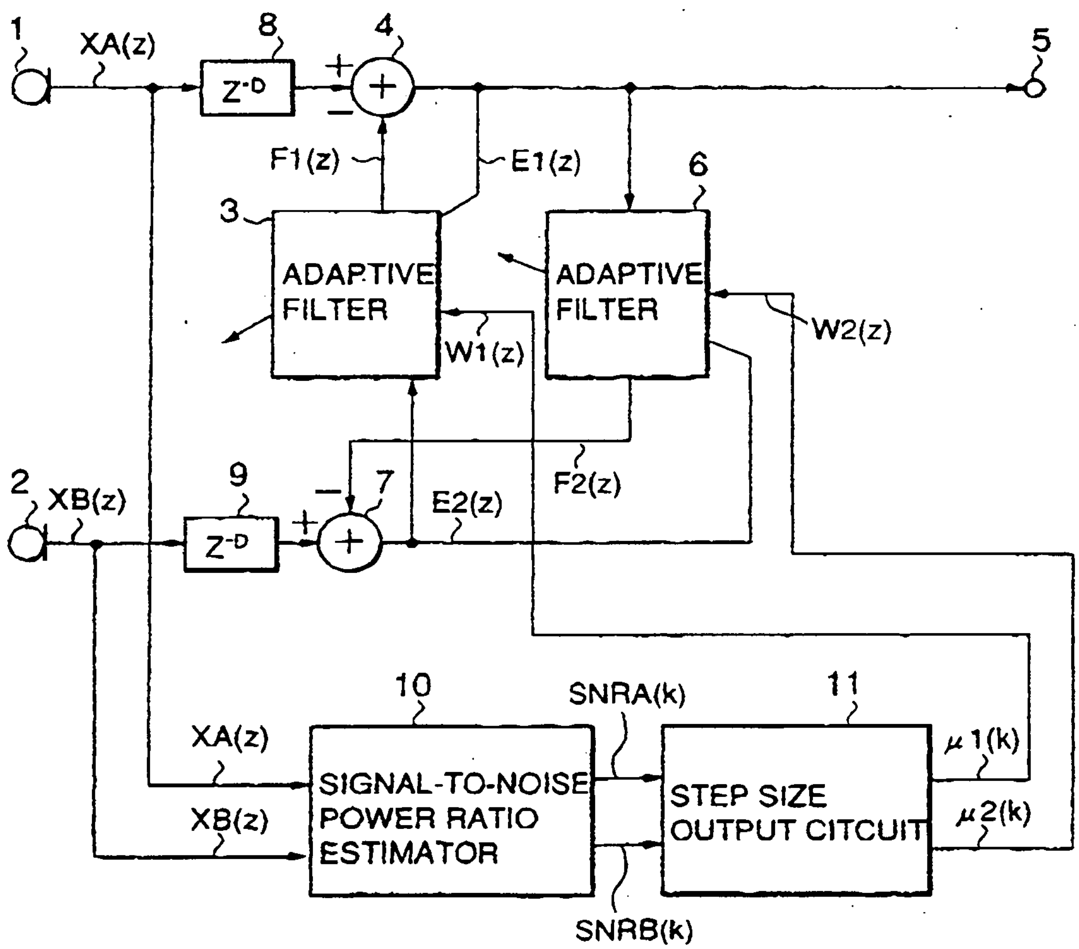

1
XA(z)
8
Z-D
4
+
−
5
F1(z)
E1(z)
6
3
ADAPTIVE FILTER
ADAPTIVE FILTER
W1(z)
W2(z)
2
XB(z)
9
Z-D
−
7
+
E2(z)
F2(z)
10
SNRA(k)
11
XA(z)
SIGNAL-TO-NOISE POWER RATIO ESTIMATOR
XB(z)
STEP SIZE OUTPUT CITCUIT
μ1(k)
μ2(k)
SNRB(k)

Fig.2

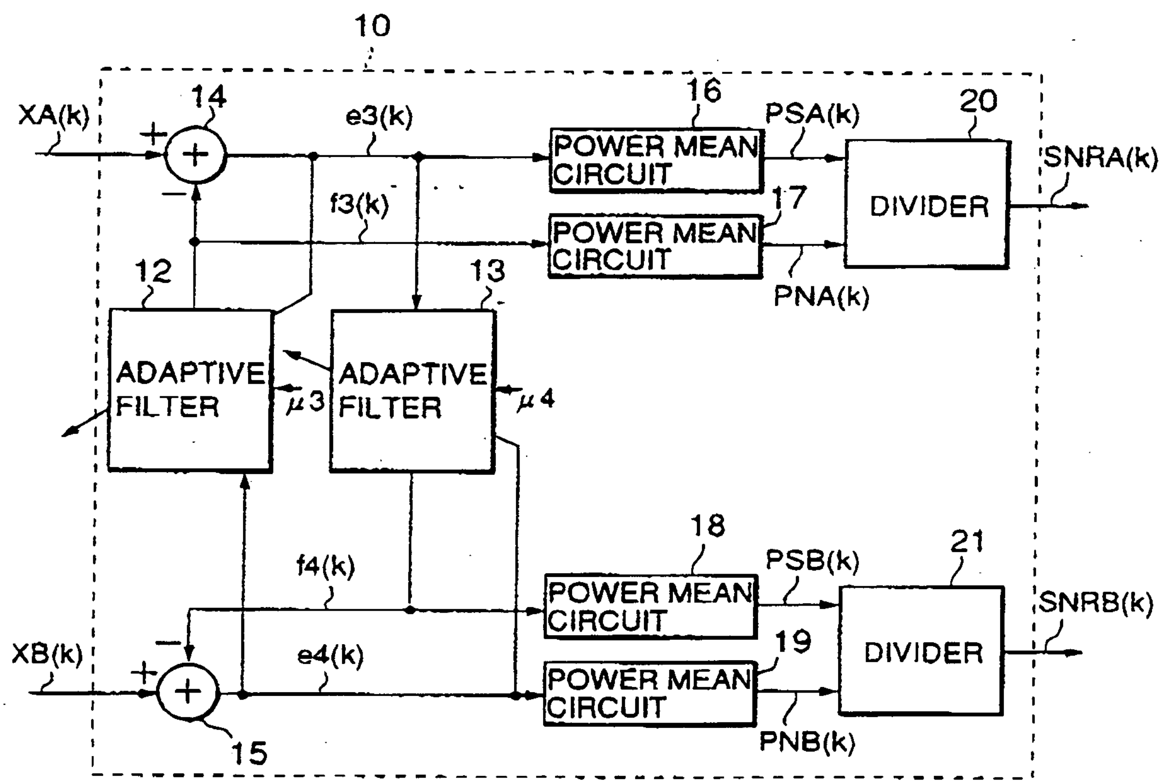

10
XA(k)
14
e3(k)
16
PSA(k)
20
POWER MEAN CIRCUIT
DIVIDER
SNRA(k)
f3(k)
17
POWER MEAN CIRCUIT
PNA(k)
12
13
ADAPTIVE FILTER
ADAPTIVE FILTER
$\mu$3
$\mu$4
18
PSB(k)
21
f4(k)
POWER MEAN CIRCUIT
SNRB(k)
XB(k)
e4(k)
19
DIVIDER
POWER MEAN CIRCUIT
15
PNB(k)

Fig.3

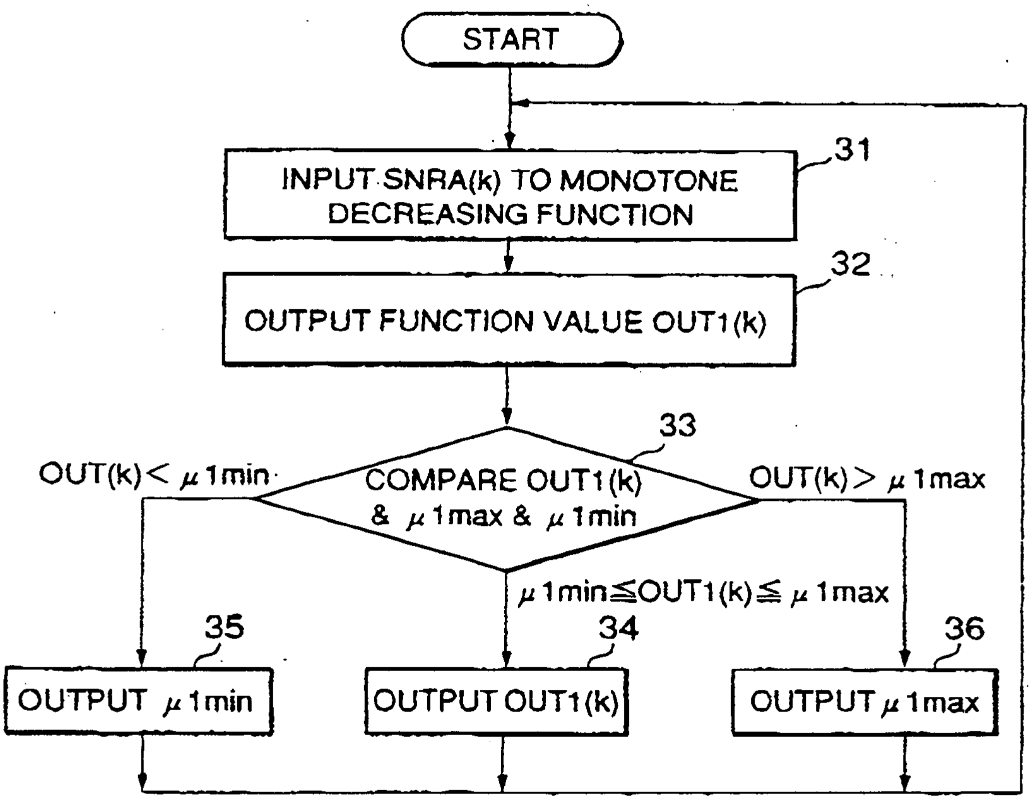

START
INPUT SNRA(k) TO MONOTONE DECREASING FUNCTION
31
OUTPUT FUNCTION VALUE OUT1(k)
32
COMPARE OUT1(k) & μ1max & μ1min
33
OUT(k)< μ1min
OUT(k)> μ1max
μ1min≦OUT1(k)≦ μ1max
35
34
36
OUTPUT μ1min
OUTPUT OUT1(k)
OUTPUT μ1max

Fig.4

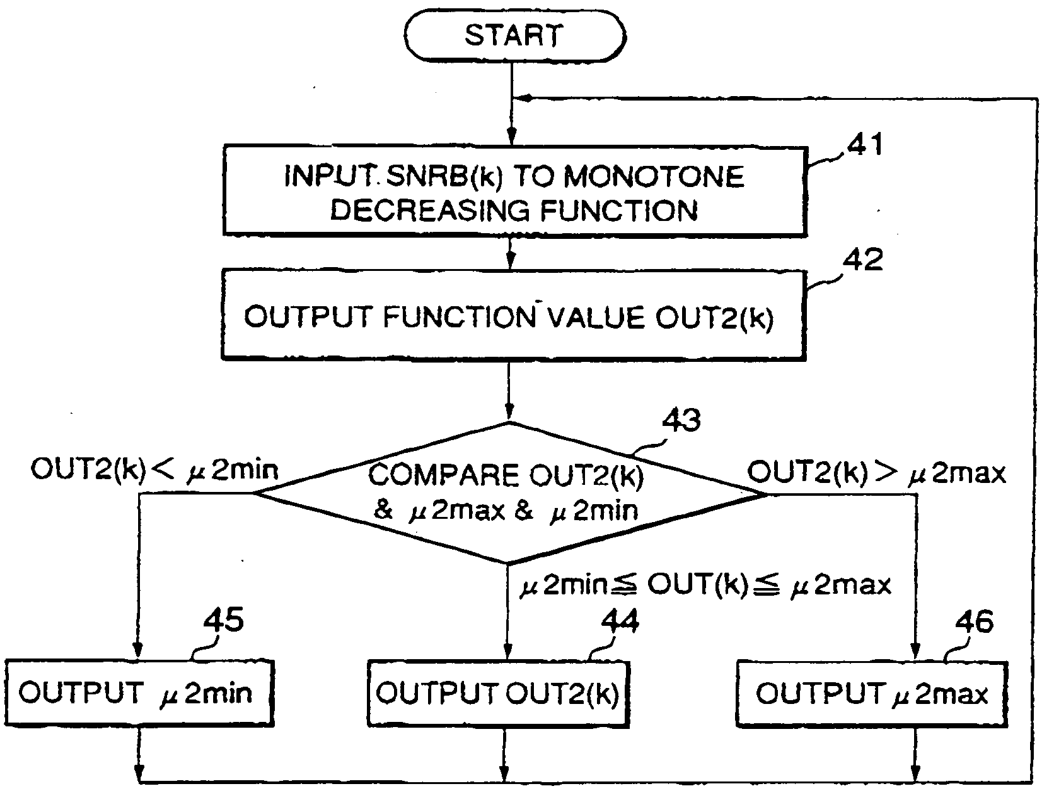

START
INPUT SNRB(k) TO MONOTONE DECREASING FUNCTION
41
OUTPUT FUNCTION VALUE OUT2(k)
42
COMPARE OUT2(k) & μ2max & μ2min
43
OUT2(k)< μ2min
OUT2(k)> μ2max
μ2min≦ OUT(k)≦ μ2max
OUTPUT μ2min
45
OUTPUT OUT2(k)
44
OUTPUT μ2max
46

Fig.5
(Prior Art)

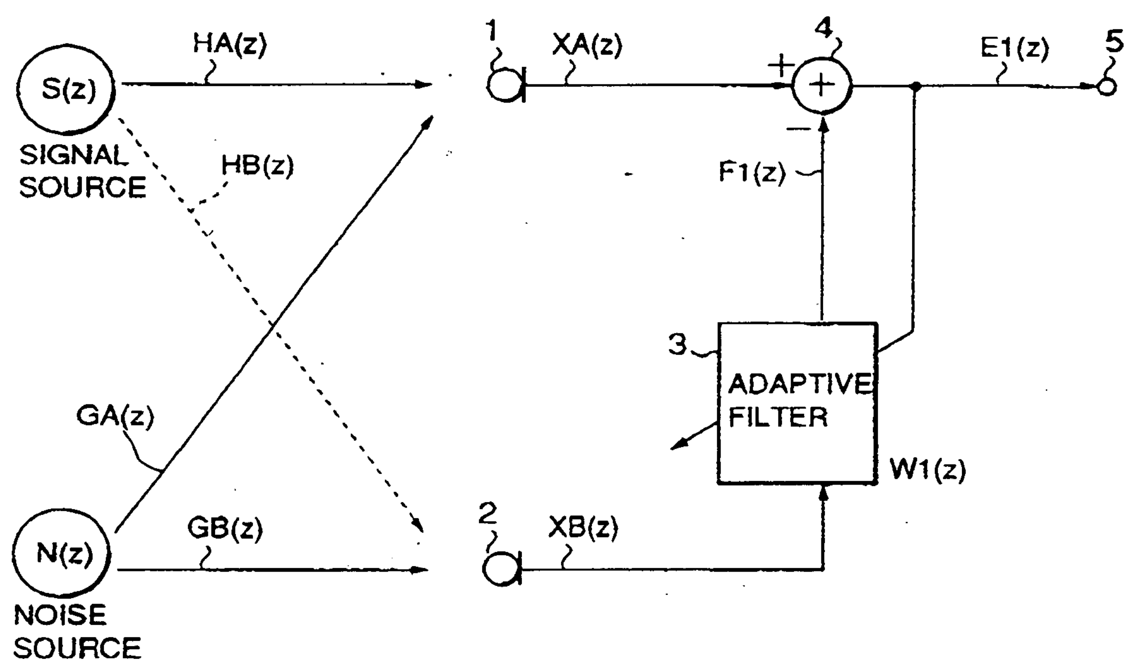
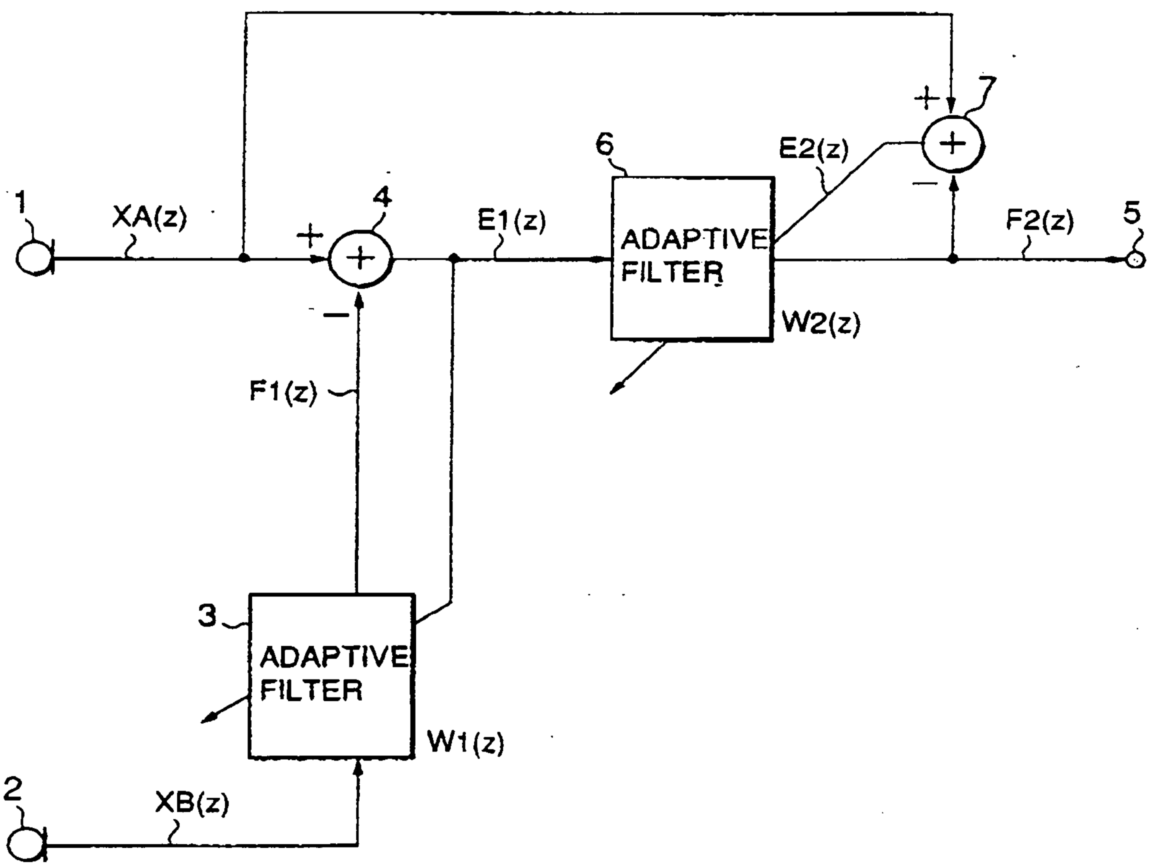


Fig.6
(Prior Art)



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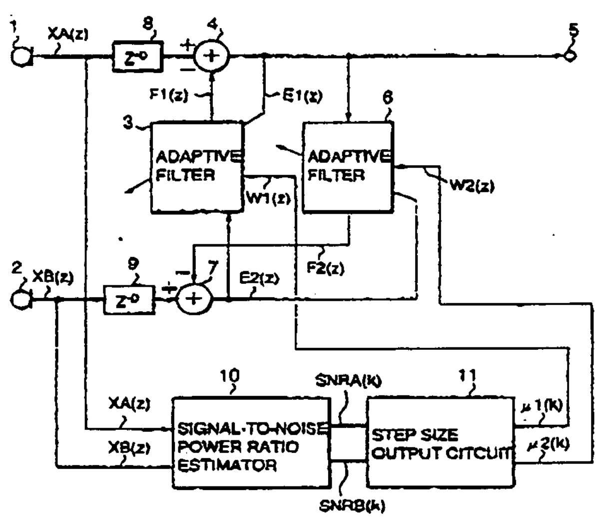
# (54) Noise canceler

(57) A noise canceler of the present invention includes a signal-to-noise power ratio estimator to which a main signal and a reference signal are input. The estimator 10 estimates the sinal-to-noise power ratio of the main signal from the mean power of a desired signal contained in the main siganl and a mean power of a noise signal also contained in the main signal. In addition, the estimator estimates the signal-to-noise power ratio of the reference signal from the mean power of a desired signal contained in the reference signal and the mean power of a noise singal also contained in the reference signal. An adptive filter for estimating the noise signal of the main signal has its step size for coefficient updating controlled in accordance with the estimated signal-to-noise power ratio of the noise signal. On the other hand, an adptive filter for estimating the desired signal of the reference signal has its step size for coefficient updating controlled in accordance with the estimated signal-to-noise power ratio of the reference signal. Delay circuits are provided for compensating for a delay ascribable to a power averaging procedure which a signal-to-noise power ratio estimator executes to calculate the estimated sigarl-to-noise power ratios.

Fig.1

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# EUROPEAN SEARCH REPORT

Application Number
EP 98 10 1469

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 23 December 1998 | Van Doremalen, J |

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